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SUPERSONIC TRANSPORT PROGRAM
PHASE II-C

BIMONTHLY TECHNICAL PROGRESS REPORT

CONTRACT FA-SS-66-5

D6-18110-7

SEPTEMBER 1966

SST

THE BOEING COMPANY
SUPERSONIC TRANSPORT DIVISION

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SUPERSONIC TRANSPORT PROGRAM
PHASE II-C

BIMONTHLY TECHNICAL PROGRESS REPORT

CONTRACT FA-SS-66-5
D6-18110-7
SEPTEMBER 1966

SST

PREPARED FOR
FEDERAL AVIATION AGENCY
Systems Research & Development Service

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APPROVED BY

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SUPERSONIC TRANSPORT DIVISION

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ILLUSTRATIONS (Cont.)

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I SUMMARY OF PROGRAM

A. GENERAL

During the week of September 19 the FAA evaluation team of 160 members visited the plant to carry out the "on-site" evaluation of the Boeing proposal. The first day consisted of reviewing the operations of the commercial airplane division, a summary of the Boeing proposal and presentation of the full scale SST mockup. During the following four days the FAA representatives met with the Boeing counterparts to discuss in detail the performance, systems, management, costs and economics of the SST airplane.

Domestic airlines visited the Boeing plant for the SST proposal briefing during the period of Sept. 7 through 16. A symposium for the non U.S. airlines was held at the Boeing plant on Sept. 27 and 28. A report on these visits is made in Section IV.

A considerable portion of the activities of the SST personnel during this month was devoted to the preparation of data for use during this evaluation and airline visits.

B. MOCKUPS

A full scale mockup of the airplane and separate full scale mockups of the engine installation, wing pivot, accessory drive and environmental control systems, electrical and electronic racks, and passenger and cargo provisions were completed.

C. FUSELAGE

Assembly tools have been completed and fabrication of the full size crew compartment has been started.

D. POWERPLANT STRUCTURE

On-site review of the Aerojet and Rohr proposals for the SST Propulsion Pod was accomplished in September and source selection is scheduled during October.

E. EMPENNAGE

Design of empennage structure is continuing with emphasis on provisions for system components and engine supports. The assembly of the composite stabilizer structure is nearing completion and test fixture is under construction.

I. Summary of Progress (continued)

F. ELECTRICAL POWER SYSTEM

Refinements in the design of the Electrical Power System have resulted in the windmilling power capability to the VSCF generators. This feature permits the use of windmilling power for engine ignition purposes and reduces the size of the standby battery source required to meet the 4 engine out requirement.

G. ENGINE INLET DEVELOPMENT

An inlet flow field survey was made on both engine installations. The inlet local Mach number during cruise at body angle of attack of 6° was found to be 2.7 for the G.E. inlet position and 2.75 for the P&WA inlet position. It is also noted that the airplane can maneuver through angle of attack range with only a 2 degree inlet local angle of incidence.

II PROBLEM REPORT

Honeycomb Panel Characteristics Not Yet Substantiated for Long Life at High Temperature and High Sonic Fatigue Environment.

Honeycomb construction has been tested at elevated temperature of 450°F using the highest sonic levels anticipated for any SST structure. It was also tested during unheated conditions during ground operations where maximum noise levels occur. The panels tested at room and elevated temperature were subjected to high sound levels without failure. Details of panels tested at temperature, unheated and simulated damaged conditions are presented in Section 11003.

The thermal stability of polyimide resin systems is anticipated and proven both by theoretical and experimental research. Aromatic compounds have been known for their exceptional thermal stability for many years. Polyimides contain a high proportion of aromatic segments. Thermal aging of reinforced polyimide structures and adhesives confirms the theoretical prediction of elevated temperature stability.

The thermal stability of a resin system is established by its weight stability at elevated temperatures. Thermogravimetric Analysis (TGA) is a basic tool for this evaluation. It has been shown that during exposure to a specific elevated temperature organic resins first lose some weight and strength, then level out and remain stable. This has been established for silicone resins by Dow Corning under government contract and verified in the aircraft industries. Polyimide resins subjected to TGA evaluations were confirmed on laminates, adhesives, and core and show that stability begins after 1,000 hours at 450-500°F and is established at 3,000 to 5,000 hours. Data has been obtained up to 18,000 hours on adhesive structures at these temperatures and the acquired stability has been retained and should remain stable for at least 30,000 hours.

Glass fabric reinforced polyimide honeycomb core is currently being evaluated for integrity at 450 and 500°F. Standard weave core has been heat aged for up to 10,000 hours at temperature. Mechanical properties of this material remain relatively constant throughout the 1,000 to 10,000 hour times. Bias weave core has been heat aged to 5,000 hours and values parallel, at significantly higher levels, those of standard weave.

The data of Fig. 3-26, page 90 of Air Frame Design Report Part D showing the sear strength retention at 500°F of polyimide adhesives on 6-4 titanium has been extended to include 18,000 hours of continuous aging. No significant structural losses have occurred during the additional 3,000 hours of aging. The strength stability indicates the shear strength - sonic fatigue correlations developed after short time temperature aging are still valid after heat aging.

Up to 10,000 hours of exposure in air to 400 and 500°F have been accumulated on glass reinforced polyimide laminates. The recent results when plotted on cures of Fig. 3.14 through 3.25 of V2-B2707-8 indicate that there has been no significant structural property reduction since a leveling off at 3,000 to 5,000 hours.

It should be noted that polyimide structures (core, laminates, and adhesives) have been heat aged in air circulating ovens. The specimens are also cut before aging and therefore have much more surface exposed to oxygen than is present in large whole panels. Under actual flight conditions the polyimide structures are exposed to 1/25th the amount amount of oxygen in a sealed or very limited exposed structure.

Based on the wealth of data gathered on the polyimide system it is no longer considered to be a problem area, and design requirements for the B-2707 can be met. However, continued work will be concentrated on further improving material properties and processing procedures. Further sustaining of thermal stability by exposure of polyimide bonded structures to elevated temperatures will be continued up to and beyond 30,000 hours.

III DESCRIPTION OF TECHNICAL PROGRESS

10. AIRFRAME – GENERAL

1002. Design Analysis

10020. DESIGN ANALYSIS - GENERAL

(1) Design Support organizations evaluated 15 supplier bid proposals during this report period to determine their adequacy for reliability, maintainability, safety, human engineering, and standardization. This evaluation included the proposals of four bidders for the automatic flight control system.

(2) The Design Support organizations also participated in numerous trade studies during this report period. The trade studies included the following:

Quantity	Subject
(3)	Wing
(5)	Body
(21)	Passenger Accommodations
(numerous)	Systems
(1)	Variable Sweep (Wing)

III. Description of Technical Progress (continued)

10021. AERODYNAMIC ANALYSIS

(1) Low Speed Configuration

The Phase II-C FAA low speed evaluation model SA 981 was tested in the University of Washington Aeronautical Laboratory wind tunnel from Aug. 16, 1966 to Aug. 24, 1966. The test was conducted to determine the low speed performance and stability and control characteristics of the B-2707 airplane configuration. A photograph of the model is shown in Fig. 1. Details of the model geometry and a definition of the slat and flap deflection angles are shown in Fig. 2. The model is a 0.037 scale of the B-2707 airplane and has incorporated a spanwise wing twist distribution corresponding to a typical 1 "g" takeoff climb condition.

Several flap deflection configurations were tested, ranging up to the maximum flap deflection of 30/50 degrees. A typical set of test results with controls neutral are shown in Fig. 3.

The SA 981 model flap system gave improved flap lift capability when compared to the level obtained on the previous low speed development model SA 857 as shown in Fig. 4. The flap on the SA 981 model was made to represent the constant percent wing chord flap of the B-2707 airplane while the flap on the SA 857 was of constant chord. This difference in flap geometry contributes to the improved flap lift effectiveness. Trimmed performance levels are compared on a L/D boundary basis at constant angle of attack in Fig. 5. The favorable trimmed performance level of the SA 981 model is a result of the improved flap lift effectiveness and differences in the tail geometry between the two models. The SA 981 model tail is twisted to align with the wing contours in the wings-aft configuration while the SA 857 model had a flat "slab" tail. This tail twist moves the center of loading outboard and aft on the tail and has resulted in a lower tail drag, probably due to improved span loading. Further geometrical refinements to the model are expected to result in further performance gains.

Based on the SA 981 performance level, a 10/30 degree flap deflection would be used for takeoff operation. This compares to a 20/40 degree takeoff flap deflection quoted in the Phase III Proposal. The maximum flap deflection 30/50 degrees is used for landing operation.

(2) High Speed Configuration

Test data obtained with the wind tunnel model that has been sent to NASA Langley for lift-drag evaluation have been analyzed. The results of that analysis have been compared with the lift-drag characteristics that were presented in the Phase III Proposal document V?-B2707-3. Generally speaking, there is no significant change in the lift-drag characteristics at cruise. A complete analysis has been prepared and presented to the FAA evaluators during on-site inspection.

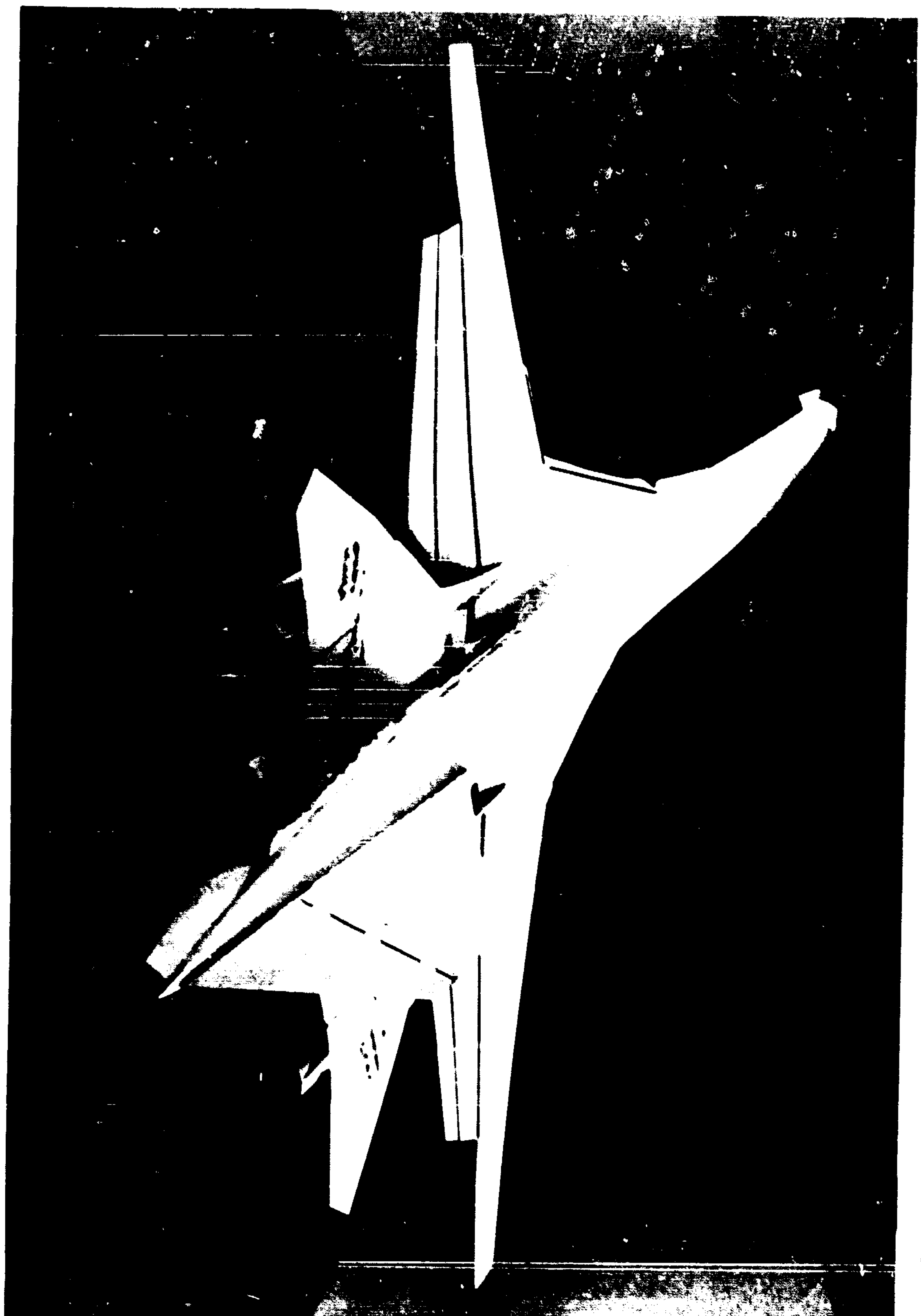
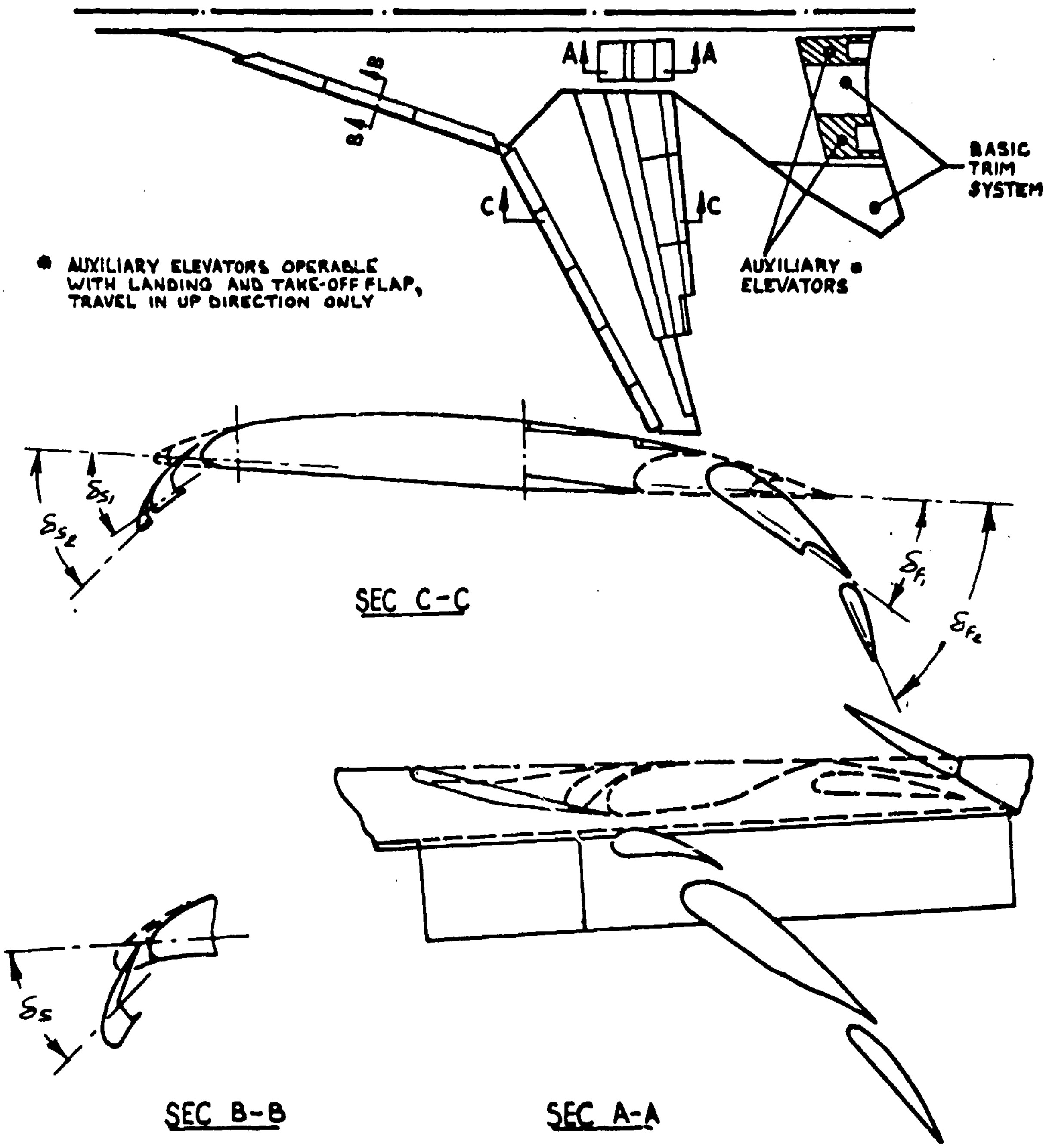


Fig. 1 FAA Low-Speed Evaluation Model SA 981



TYPICAL FLAP DEFLECTION CALL OUT

OUTBOARD

$\delta_{F1} / \delta_{F2}$

$30° / 50°$

TYPICAL SLAT DEFLECTION CALL OUT

WING	STRAKE
$\delta_{S1} / \delta_{S2}$	δ_S
$10°/35°$	$40°$

Fig. 2 Model Geometry

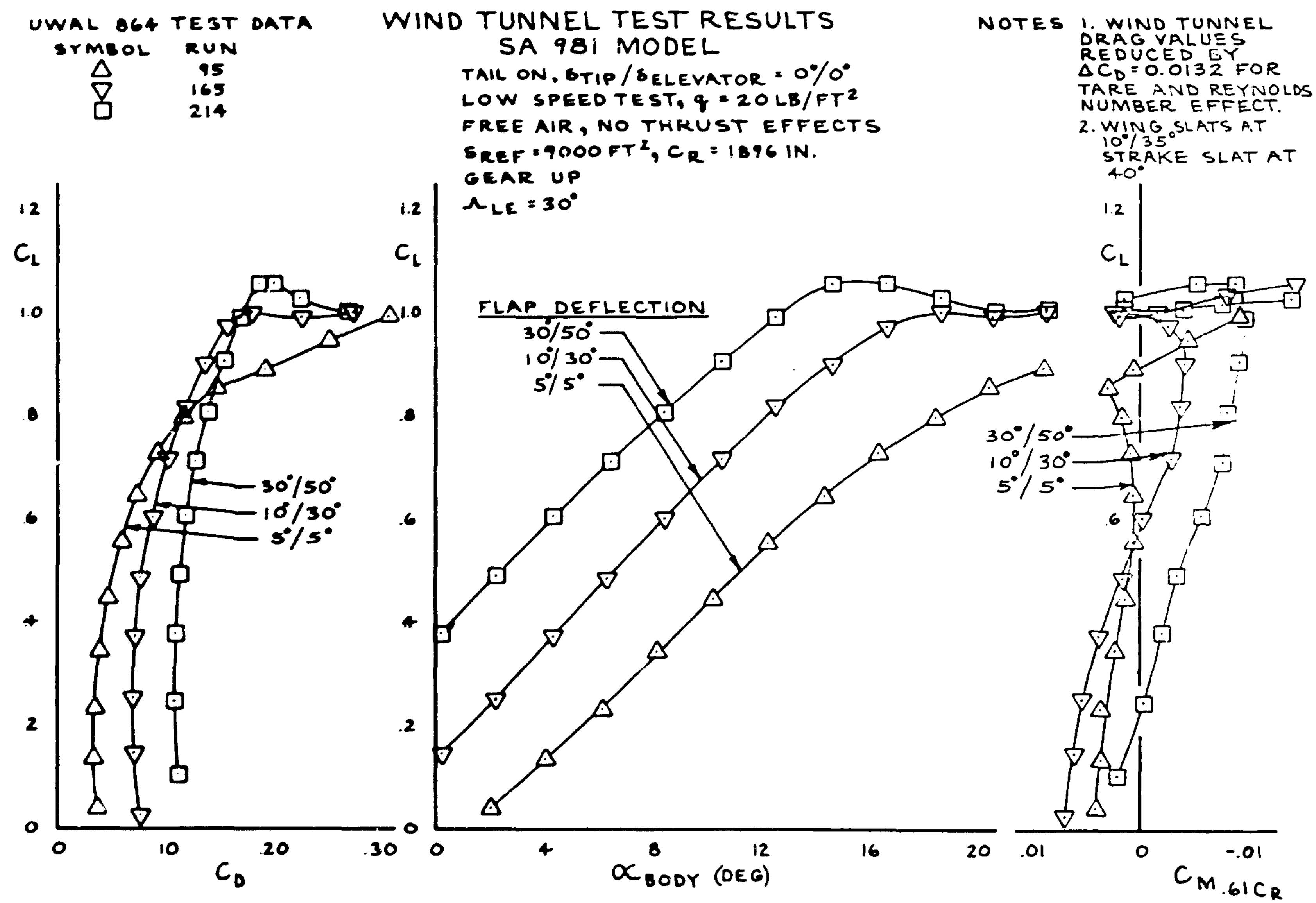


Figure 3. SA 981 Model Wind Tunnel Test Results

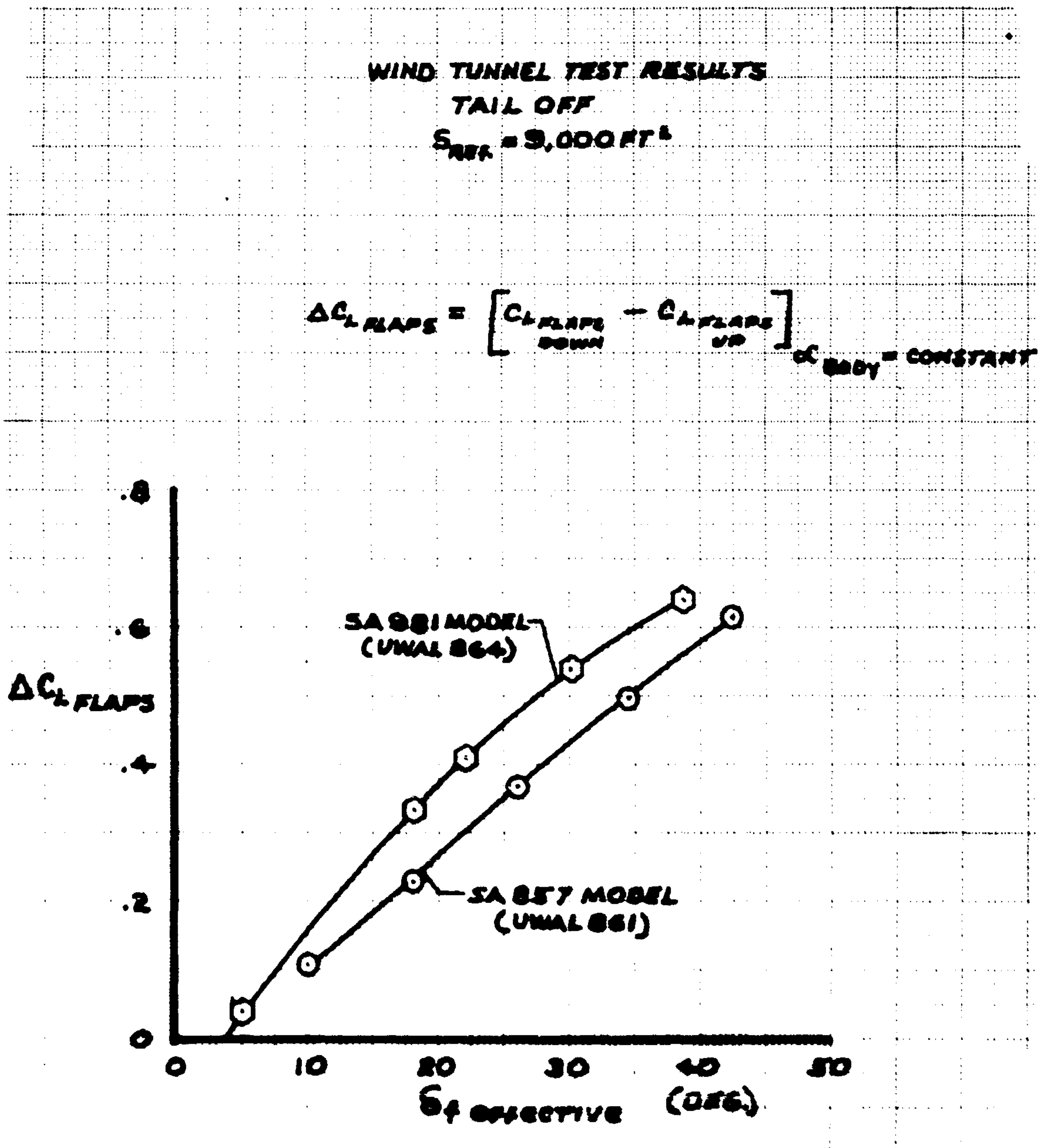


Fig. 4 Flap Lift

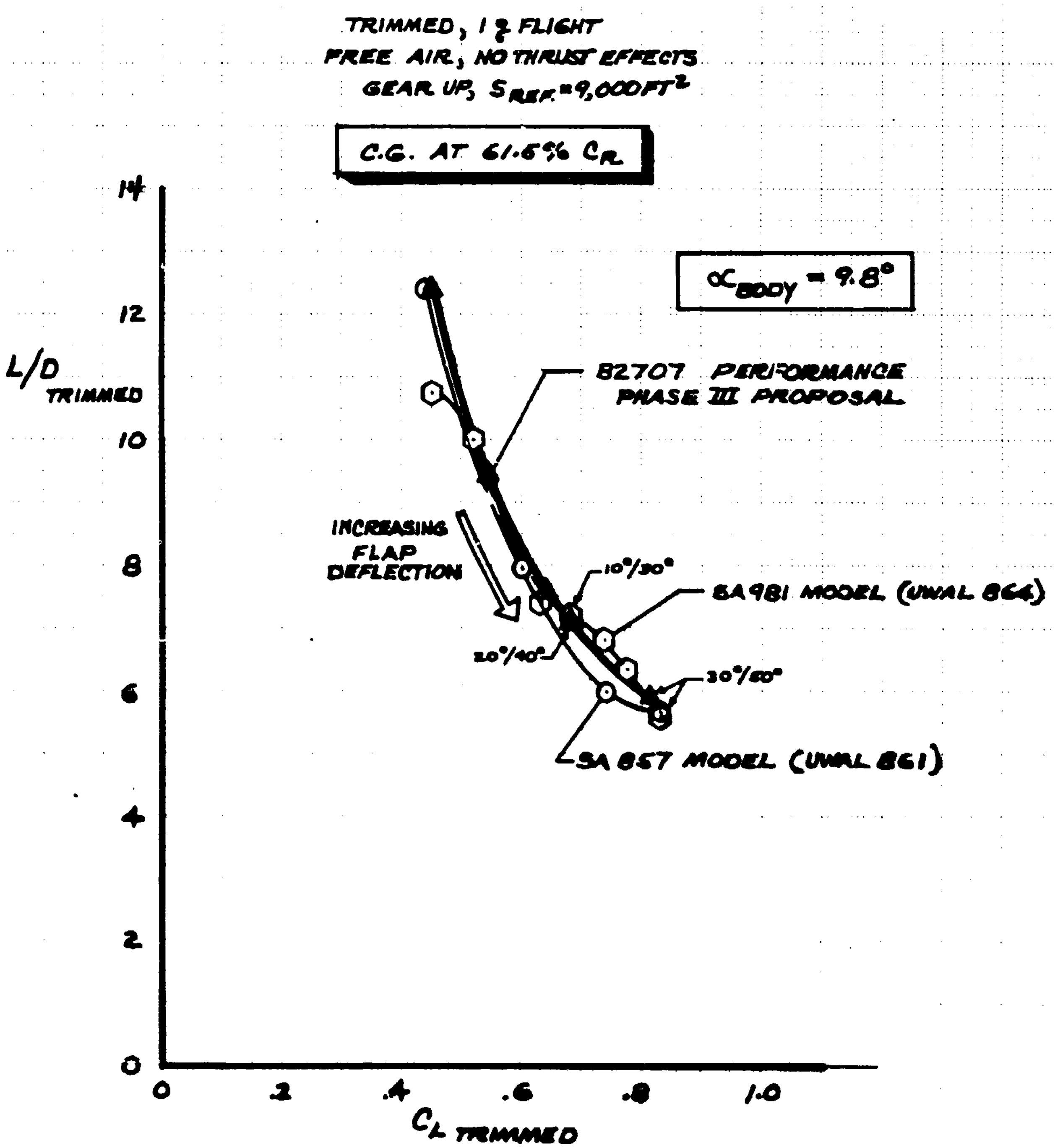


Fig. 5 Comparison of Low-Speed Performance

III. Description of Technical Progress (continued)

10024. AERODYNAMIC WIND TUNNEL TESTS

Aerodynamic testing during August and September and proposed through November is shown on the schedule chart, Fig. 6. Wind tunnel occupancy time for aerodynamics totalled 657 hours during August and September.

(1) Tests Completed

University of Washington Aeronautical Laboratories (UWAL) Test No. 864, SA-981I-1, .0367 scale. Tested August 16 through 27. Purpose: To evaluate low speed FAA evaluation model.

Boeing Transonic Wind Tunnel (BTWT) Test No. 988, SA-984I-1, .015 scale. Tested August 24 through 29. Purpose: To evaluate Λ = 42 degree transonic FAA evaluation model.

BTWT Test No. 989, SA-983I-1, .015 scale. Tested August 29 through 31. Purpose: To evaluate Λ = 72 degree transonic performance of FAA cruise evaluation model.

Boeing Supersonic Wind Tunnel (BSWT) Test No. 365, SA-977I-1, .015 scale. Tested August 1 through 3 and 8. Purpose: Conclusion of this earlier test to measure drag and preliminary performance of an advanced B2707 midwing configuration.

BSWT Test No. 363, SA-966I-2, .0152 scale. Tested August 3 through 6. Purpose: Conclusion of this earlier test to obtain B2707 supersonic drag data for Phase IIC proposal.

BSWT Test No. 366, SA-983I-1, .015 scale. Tested August 19 through 29. Purpose: To evaluate performance of supersonic FAA evaluation model.

BSWT Test No. 367, SA-966I-3, .0152 scale. Tested September 14 through 23. Purpose: To measure drag on B2707 double aisle, body configurations.

(2) Future Test Planning

Tests to give improved longitudinal control during landing approach at forward center of gravity locations are now planned using the low speed evaluation model (SA-981). Related tests to improve transonic trim and control will use the Λ = 42 degree evaluation model (SA-984). Supersonic cruise L/D verification testing will begin about October 10 using the SA-966 model.

	WIND TUNNEL MODEL NUMBER AND DESCRIPTION	AUG	SEPT	OCT	NOV
LOW SPEED	SA-981 I-1 .0367 scale Boeing test of FAA Eval. Model		UWAL	864	
	SA-981 E-1 .0367 scale Pitch control improvement studies				
	SA-967 E-1 .0367 scale B-2707 Config. development model	Model cancelled. Development program to be carried out on SA-981 Model			
TRANSONIC	SA-984 I-1 .015 scale Boeing test of $\Lambda = 42^\circ$ FAA Eval. Model		BTWT	988	
	SA-983 I-1 .015 scale Boeing test of $\Lambda = 72^\circ$ FAA Eval. Model		BTWT	989	
	SA-984 I-2 .015 scale Transonic trim and control studies				
SUPERSONIC	SA-977 I-1 .015 scale Aero development model drag tests	BSWT	365		
	SA-966 I-2 .0152 scale B2707 supersonic proposal drag data	BSWT	363		
	SA-983 I-1 .015 scale Boeing test of FAA Eval. Model		BSWT	366	
	SA-966 I-3 .0152 scale Double aisle body config. development			BSWT 368	
	SA-968 I-1 .015 scale Aeroelastic effects model				
	SA-966 I-4 .0152 scale Cruise L D verification program				

Tests Completed | Tests Planned

Fig. 6 Aerodynamic Wind Tunnel Test Schedule

III. Description of Technical Progress (continued)

1003. Maintainability

The main effort of the Maintainability Unit during this period has been directed to the final preparation of proposal documentation, and presentations for the FAA and airline evaluation teams.

10030. GENERAL

Document D6A10263-1, "Maintenance Concept - Supersonic Transport," was available for review during the on-site evaluation. This document presents the baseline maintenance concepts for the B2707 to assist the designers in interpreting reliability and maintainability requirements during the development of the B2707 maintenance program.

Document D6-9458, "Maintenance Design Guide - Commercial Supersonic Transport," was updated and revision copies issued to all of the B2707 design sections. The revised version now has been sectionalized to match the SST project subsystem organization and now includes coverage for all subsystems, added objectives, and added information on airline maintenance practices.

During the last two months, the Maintainability Unit has made inputs to numerous trade studies.

10031. MAINTAINABILITY ANALYSIS

Document D6A10264-1, "Maintainability Allocations - SST," was completed and released. This document contains the maintainability maintenance man-hour allocations and mean maintenance task time allocations by major subsystem and the total airplane. Included are those data used as the basis for the derivation of the SST allocations and those factors considered for extrapolation to the SST environment. The report and its contents will be updated as new information and requirements are made available.

Document D6A10265-1, "Maintainability Analysis," was completed and released. This document is a report of the predictions of maintenance time and effort required as the result of the present status of aircraft design. Included are data related to all major systems pertinent to mean corrective time, maintenance man-hours for "on airplane" unscheduled remove/replace actions, and dispatch delays. The basic purpose of the data is to serve as a means of measuring design progress. As new data are developed, the report will be updated to reflect those changes and their effect on systems maintainability.

Document D6A10266-1, "SST Operations and Maintenance Simulation Model," was also completed and released during this report period. The document presents a simulation model for the study of the effects of maintenance and maintenance costs on airline schedules and operations. The model as presently programmed is capable of providing data for use

III. Description of Technical Progress (continued)

10031. Maintainability Analysis (continued)

in the evaluation of varying inspection schedules, maintenance task times and removal rates for various operational periods. Included in the document are the rationale underlying the model and the means by which data are programmed for analysis. The report and its contents will be updated as additional data becomes available.

These documents were provided for review by the FAA and airline evaluators during their respective on-site evaluations. Copies have been provided to those evaluators upon request.

10032. MAINTENANCE ANALYSIS

The maintenance analysis of remove/replace tasks was completed for over 2,000 major Line Replaceable Units in the airplane which could require replacement due to unscheduled malfunctions. This analysis has included the identification of the LRU, the task time, the number of personnel required, the manhours, and the ground support equipment required to accomplish the task. The maintenance analysis will continue to be updated as refinements are introduced and as further definitions of the details of the design are evolved.

10033. MAINTAINABILITY STUDIES

Aircraft Integrated Data Subsystem Specification D6A10090-1 was released during the reporting period. This specification defines the objectives, criteria, and configuration and establishes the requirements for performance, design, test, and qualification of the Aircraft Integrated Data System (AIDS) for the prototype model supersonic transport airplane.

The AIDS feasibility and requirements study was completed during this period. The study indicates that it will be cost effective to install an AIDS system on the SST on a pure maintenance basis. The study documentation (Evaluation of the Aircraft Integrated Data System, D6A10342-1) was released on a preliminary basis for the FAA on-site review. This document will be completed for release early in October.

1004. Reliability

10040. RELIABILITY - GENERAL

Departmental Operating Procedure 9-2200-011, Subject: Design Support/Product Support Design Objectives and Requirements, has been issued. This procedure defines the process for the release, control, and documentation of design objectives and requirements (including reliability) generated by the Design Support and Product Support organizations.

10040. Reliability - General (continued)

Mathematical Models

During this period, the Automatic Reliability Mathematical Model (ARMM) program was used to update the in-flight reliability predictions. Subsystem and airplane level computer runs were made to include latest design configurations.

A complete initial run was made of the Fleet Integrated Reliability Mathematical Model (FIRMM). The analysis used a North Atlantic route system for scheduled flight and ground times (less stringent than the 90 minute turn-around and 30 minute throughstop times used in the manual analysis), subsystem reliabilities from the ARMM program, and repair probability data contained in D6A10265-1, Maintainability Analysis.

Although there are variations in results among the methods used, these models, along with the manual analyses described under 10042 (below), indicate that the reliability objectives are achievable.

10041. RELIABILITY DESIGN SUPPORT

The following documents have been released during the report period:

- D6A10064-2(A) - Reliability Analysis Document--Accessory Drive and Engine Starting
- D6A10064-3(A) - Reliability Analysis Document--Aircraft Integrated Data System
- D6A10064-4(A) - Reliability Analysis Document--Automatic Flight Controls
- D6A10064-5(A) - Reliability Analysis Document--Communications
- D6A10064-6 - Reliability Analysis Document--Electrical & Lighting
- D6A10064-8(A) - Reliability Analysis Document--Flight Controls
- D6A10064-11 - Reliability Analysis Document--Landing Gear
- D6A10064-12(A)- Reliability Analysis Document--Navigation and Flight Instruments
- D6A10064-13 - Reliability Analysis Document--Passenger, Cargo, & Crew Accommodations

10042. RELIABILITY ANALYSIS

The system level Failure/Error Mode, Effect, and Criticality Analysis has been completed and incorporated into D6A10064-1(A).

A list of equipment required for dispatch, subsonic flight, and supersonic flight, whether over land or water, has been completed for each subsystem. This list is used for reliability, safety and maintainability analysis purposes and will, ultimately, be used during the certification test program to help establish Minimum Equipment Lists for dispatch. Completion of these lists and subsequent

III. Description of Technical Progress (continued)

10042. Reliability Analysis (continued)

analysis showed that the mean unscheduled maintenance task time derived from a sample of the total subsystem items would not change as a result of considering only those items which were critical for dispatch. In other words, information from a sample of the total population was equivalent to that from the total of the dispatch critical items.

A dispatch reliability analysis was completed. This analysis (detailed in document D6A10265-1, Maintainability Analysis) considers, on the subsystem level, equipment required to be operational for dispatch as determined from the lists noted above, the probability that this required level of equipment will not be available upon flight completion, and the distribution of time available for maintenance. The result is the probability that necessary repairs cannot be made in the available ground time. This analysis showed that the inherent dispatch reliability goal for the airplane excluding engines of 97.4 percent can be met and predicts the value to be 98.8 percent.

Reassessment of in-flight and dispatch reliability allocations previously accomplished was completed during this period to Level 3 of the Work Breakdown Structure for inclusion in subsystem specifications.

10044. DESIGN SUPPORT DATA CENTRAL

The Design Support Data Central has continued to furnish historical problem data and failure and maintenance rates to support reliability, maintainability and safety analyses. During this period the following major releases were made:

- Reliability and Maintainability Prediction Standards - SST Program, D6A10095-1 (updated)
- Data Index - Design Support Data Central, D6A10176-1 (updated)
- Design Support Data Plan - SST Program, D6A10245-1 (first release)
- Failure Reporting & Corrective Action System - SST Program, D6A10245-2 (first release)

Data analysis activities included continuation of failure and maintenance rate data extraction for commercial subsonic jets, and conclusion of a study of 727 out-of-service times.

The Reliability and Maintainability Prediction Standards document was converted to EDP format for ease of document maintenance. Inclusion of SST application data is about [illegible] percent complete in the latest document revision.

Development of a computerized data analysis program is continuing on schedule. Several trial actuarial runs were completed during this reporting period.

10044. Design Support Data Central (continued)

Coordination of the data central operating plan and the corrective action system description was concluded for the Proposal effort, and releases were made of both documents. Further development of Phase III data system planning will take place during the remainder of Phase IIC.

1007. Safety

10070. SAFETY GENERAL

A System Safety Program flow chart was prepared for use in the Engineering Management Systems Planning Center. This flow chart will serve as a training device for the indoctrination of new engineers in SST engineering organizations. The purpose will be to explain the functions of the System Safety Unit and Safety program interfaces.

Two additional members of the Safety unit attended the University of Washington's intensive course on Systems Safety Analysis. This course covers Fault Tree methods, probability and statistics, and the use of computer simulation in analyzing systems for undesired events.

10071. DESIGN SUPPORT

Safety analysis workbooks for each airplane subsystem have been assembled as working tools by the safety analysts. The books contain design and test information as well as the results of hazard analyses and safety check lists. These workbooks are intended to provide a continuity between Phase IIC and Phase III activity.

A study of Boeing data has indicated that the commercial Boeing jet fleet experiences an uncontained engine failure approximately every 607,000 engine hours. Of these failures, approximately 33 percent result in airframe damage. Analysis of the B-2707 engine installations and the adjacent areas of the airplane associated with turbine or compressor disc failure are continuing to optimize the location of components, plumbing, cabling and wiring to maintain the inherent redundancy and operational integrity of flight critical systems.

Numerous formal trade studies were completed. Design alternatives for the waste water system, passenger and crew oxygen system, floor beam and panel construction and the variable nose geometry configuration were among those studied. No significant safety degradation was found in the various alternatives considered but recommendations were made in each case to the designer.

III. Description of Technical Progress (continued)

10072. REQUIREMENTS ANALYSIS

Work has continued in the development of the SST Fault Tree and in the methods for quantifying events within the tree. A pilot study of the SST electrical subsystem was made to test the reliability data availability and manual methods of calculation of the probability of loss of the electrical system.

An iteration was made of the top echelon events to restructure the flight phases of the tree and to obtain a more optimized division of sub events. Initial branches of the landing phase and the subsonic wing sweep phase have been developed.

An automatic reliability mathematical model (ARMM) developed by North American Aviation was evaluated for applicability to the fault tree systems analysis program. It has been concluded that the methods presently used in the Boeing Minuteman Program utilizing Monte Carlo techniques afford inherent advantages over the ARMM and are readily adaptable to the SST fault tree.

1008. Materials and Processes

<u>Evaluation of Self-Lubricating Movable Seal and Rub Strip Materials</u>

Wear resistance of Teflon and Teflon reinforced with glass, bronze, or asbestos have been determined. Test conditions were as follows:

Load - 200 psi
Temperature - 450°F and 535°F
Speed - 5 ft/min
Motion - reciprocating at 29 cpm and ± 0.5-inch stroke
Mating metal - 6Al-4V titanium

Comparative wear resistance of these materials and for Rulon LD (ceramic-filled Teflon, reported in July Progress Report) and Boeing lubricant compact 108-67 are shown in Fig. 7. The rub strip material exhibiting the least amount of wear (most wear resistance) is the Boeing compact number 108-67. Wear of this material was only one-half that found for any of the Teflon materials tested at 450°F (0.0054-inch wear after 100,000 cycles). This material has not yet been tested at 535°F, but because of other tests discussed in earlier reports, it is expected that wear superiority of the Boeing compact materials will also be found at temperatures higher than 450°F.

Wear resistance of reinforced Teflons appears to be adequate where relatively thick rub-strips can be tolerated (to 0.20-inch). Reinforced Teflons have greater elasticity than the sintered Boeing lubricant compact materials. For applications where a rub-strip material with resistance to bending moments is needed, the reinforced Teflons could be used.

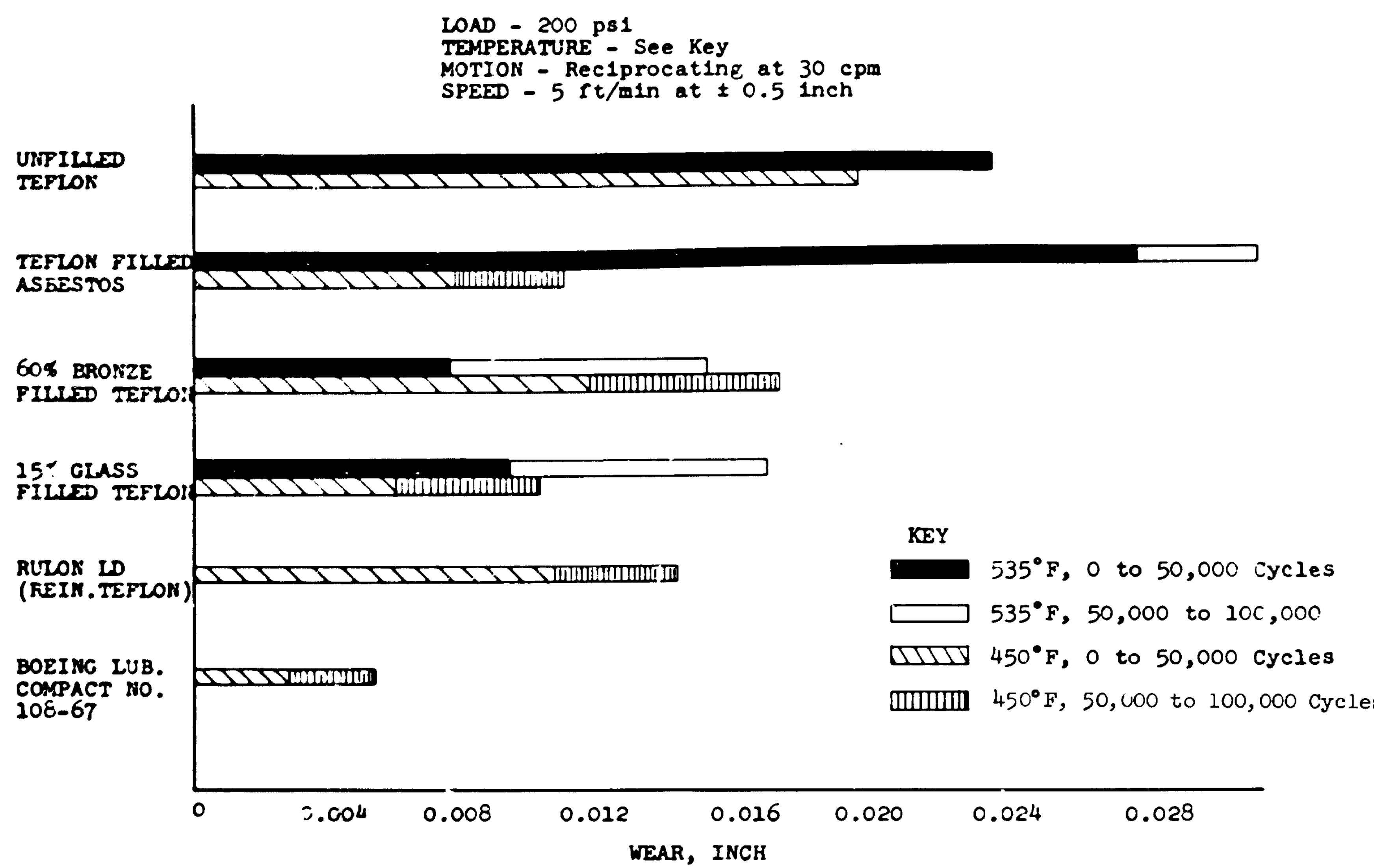


Fig. 7 Wear of Self-Lubricating Rub-Strip Material

D-1-11-7

1008. Materials and Processes (continued)

Effect of EC 1937 B/A Elastomeric Coating on the Mechanical Properties of Fiberglass Reinforced Polyimide Laminates

Polyimide laminate compression specimens were coated with 3M's EC 1937 B/A elastomeric coating to determine its effect on the thermal and hydrolytic resistance of the laminate material. Coated and uncoated specimens cut from the same panel showed no difference after thermal aging. However, the coated specimens showed approximately 100 percent better strength retention after 1000 hour aging at 450°F following water boil. The EC 1937 coating in this case is obviously able to resist the thermal environment as well as to provide a moisture barrier. (See Figs. 8 and 9.)

Structural Sandwich

Flatwise tensile strengths exceeding 500 psi at room temperature are being achieved. Correlation of this strength with edgewise compressive testing shows that this bond is in excess of that required to develop the ultimate strength in the sandwich faces.

Flatwise tensile values tested in areas where the core has been reinforced with polyimide foam average 900 psi. Development of bond strengths of this magnitude prove the integrity of wedge close-out areas.

Recent studies indicate that there is scatter in sandwich component strength due to excessive humidity in the layup area of the manufacturing facility. This area is now equipped with a dehumidifier and all future layup will be accomplished in a relative humidity of less than 30 percent.

Metal-to-Metal Area Bonding with FM-34 Polyimide Adhesive

FM-34 polyimide adhesive was used in area bonding several metal-to-metal sheets together. Some assemblies incorporated perforations in one skin on different spacings to enhance volatile removal. The adhesive was further cut in strips to incorporate a bleeder path without sacrificing panel integrity. The perforated skin assemblies produced initial lap shear values on cut and milled specimens (Fig. 10) of 1,500 psi. This value should be easily improved with further development.

High Temperature Resistant Syntactic Foams

A syntactic polyimide foam has been produced using E.I. DuPont's 4701 polyimide resin and Emerson and Cumings' Eccospheres Type SI. Foams ranging in density from 13 to 24 pounds per cubic foot have been made. Compression strengths are comparable to density vs compression strengths for rigid urethane foams. Polyimide syntactic foam properties are listed below.

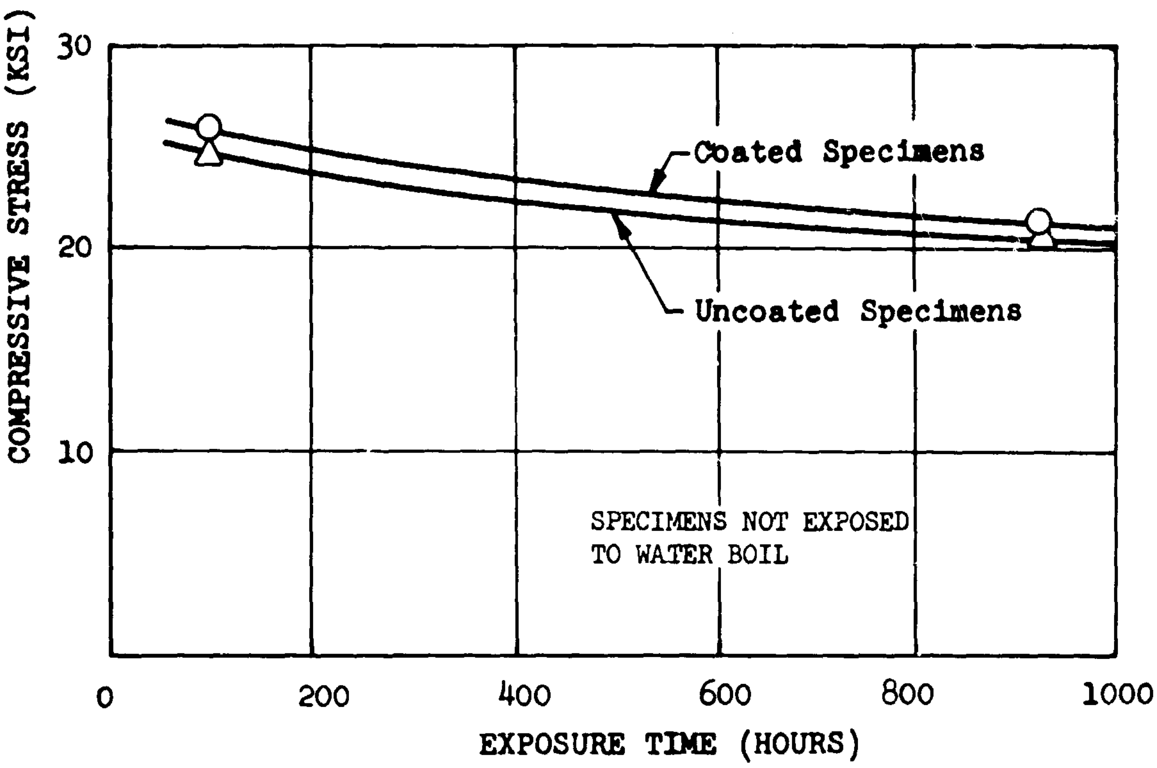


Fig. 8 Compressive Strength of Coated and Uncoated Polyimide Laminate Compression Specimens Aged and Tested at 450° F

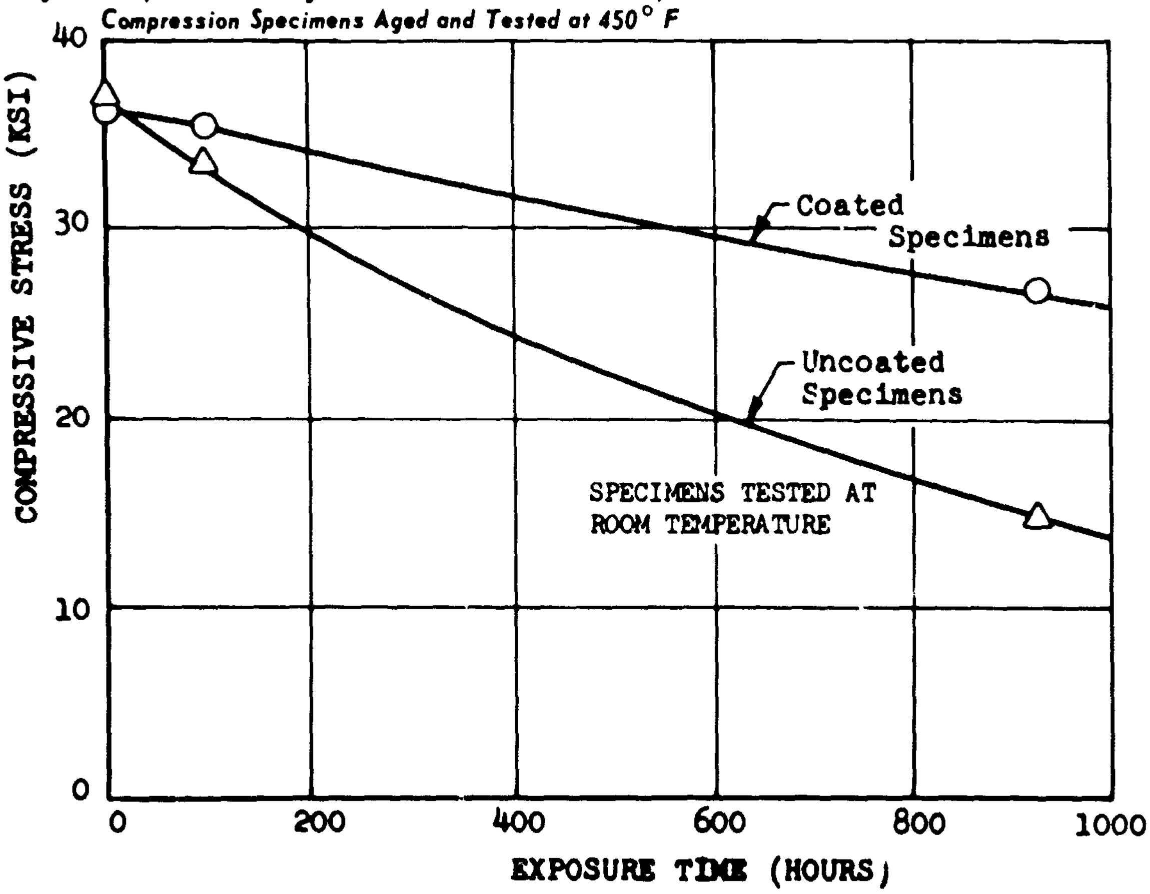


Fig. 9 Compressive Strength After a 2-Hour Water Boil of Coated and Uncoated Polyimide Laminated Aged at 450° F

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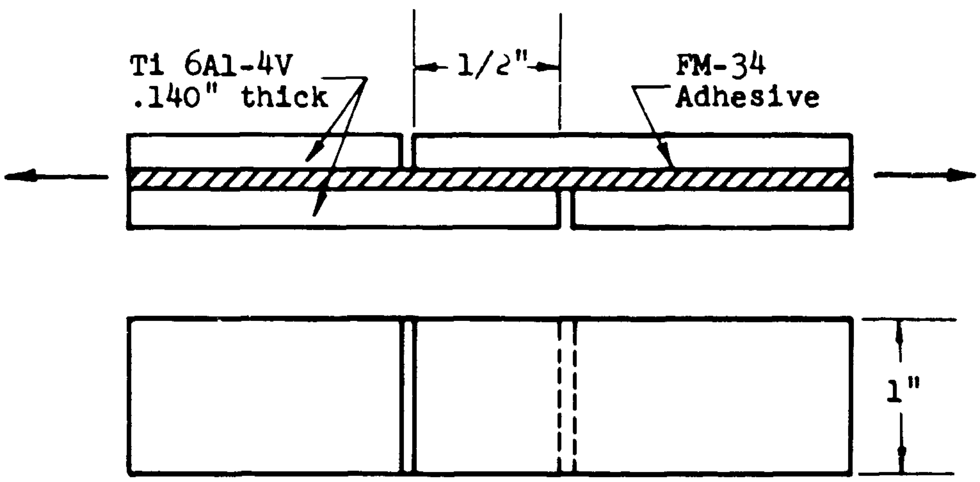

Fig. 10 Lap Shear Test Specimens

III. Description of Technical Progress (continued)

1008. Materials and Processes (continued)

Density (lb/cu ft)	Compression Strength (lb/sq in.)
13.0	328
13.6	495
15.2	467
20.0	985
24.5	1570

The 20-lb density foam with a compression strength of 985 psi is a prime candidate as a potting compound. It can be injected into a damaged honeycomb sandwich area from a pneumatic sealant gun or troweled into such structures with a spatula.

The 13-lb density foam with a compression strength of 328 psi is being considered as a supplemental candidate for fuel tank insulation.

An 8-lb-per-cubic-foot fluorosilicone syntactic foam has been produced using Dow Corning's 94-513 and Emerson and Cumings' Ecco-spheres, Type Si.

The mixture of resin, catalyst, glass spheres, and methyl-ethyl-ketone (blowing agent) is reinforced with honeycomb core that has been bonded to a titanium face skin with Dow Corning's 94-002 fluoro-silicone sealant. The entire system is cured in a 150°F oven for 20 minutes. This material is also being considered as a supplemental fuel tank insulation.

<u>Transparencies: Fiberglass Edge Attachment Inserts</u>

Fiberglass edge attachment inserts will be used in the SST windshield to reduce heat transfer into the interlayer. Pullout strength tests of fiberglass and aluminum inserts in PVB have shown that their respective adhesion to the interlayer is relatively equal, the fiberglass having a slight advantage, as shown in Fig. 11.

<u>Radomes</u>

The construction of two full-scale filament-wound polyimide nose radomes has been completed. Some difficulty was experienced with delamination and poor adhesion between layers; minor process changes were made to prevent reoccurrence. The areas with poor adhesion were repaired by stripping and replacing the affected layers. The delaminated areas were repaired by injecting a polyimide resin. A process test panel indicated that a short beam interlaminar shear strength of 2,000 psi was developed in the repair area.

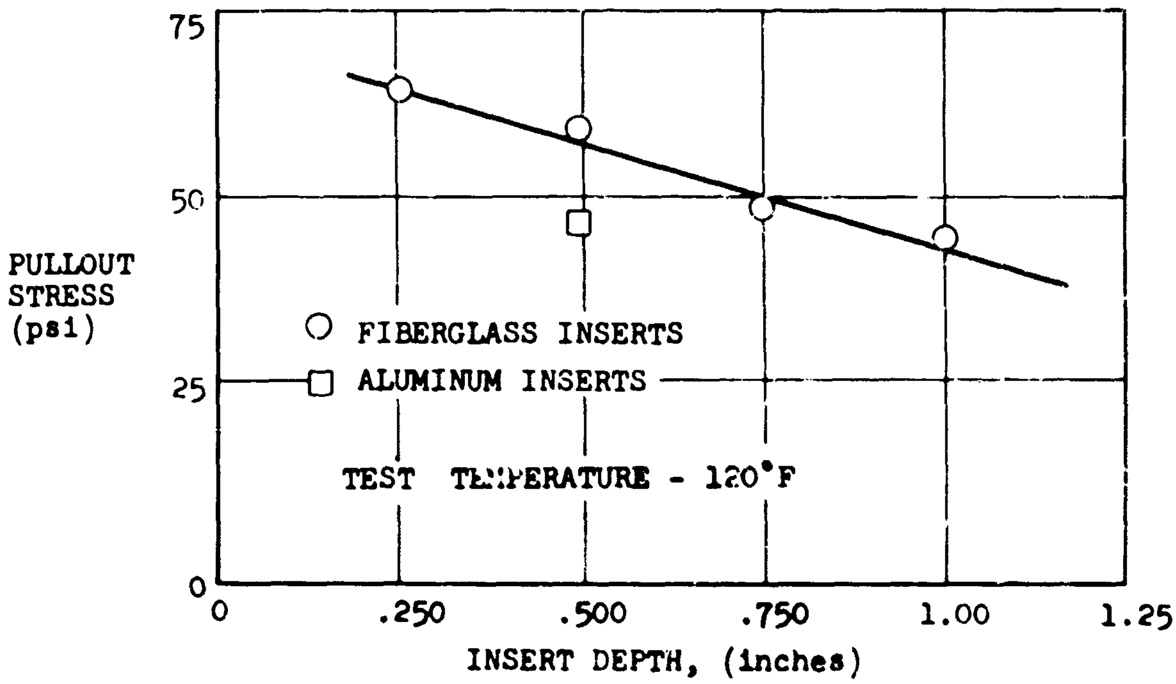

Fig. 11 Pullout Strength of Fiberglass Edge Attachment Inserts

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Mechanical Joint Fatigue Life Study

Ti 6Al-4V Rivets

It was found that the headability of titanium rivets varied considerably between different orders received from the same vendor. An investigation revealed that the time interval between hot heading and heat treatment was the only significant difference in processing procedure.

An investigation of the effect of heat treat delay was initiated by having rivets from the same lot heat treated after 8 hours, 2 weeks, and 6 weeks delay between hot heading and heat treatment. The results (see Fig. 12) show a linear reduction in headability over the 6 weeks delay period. This characteristic of the Ti 6Al-4V rivet alloy will be further investigated by use of optical and electron microscopy.

Further exposure tests of joints fabricated with 1/4-inch diameter A286 rivets show that the fatigue life loss after exposure is less for the 450°F exposure than that obtained from a 550°F exposure (Fig. 13).

Bolt and Nut Evaluation

Tension-tension fatigue test data have been obtained on Ti 6Al-4V and Ti 7Al-12Zr bolts tested with A286 nuts. Nuts used in these tests had a special thread configuration which equalizes stresses along the bolt threads. The specimens were tested at 45 percent of ultimate tensile strength (max. load), with minimum load 10 percent of maximum.

Limited data, see Table A, indicates a possible reduction in fatigue life of the Ti 6Al-4V bolts after elevated temperature exposure, but not significant change in the fatigue life of the Ti 7Al-12Zr bolts. Additional tests are planned to determine the effect of ultimate strength of the Ti 6Al-4V bolts on the fatigue life.

Bearing Retention

Coatings will be used to protect Ti 6Al-4V housings during bearing installation and removal and to increase bearing retention capability when installed by interference or other methods. Several coatings were investigated to determine their anti-galling and retaining properties.

Coatings which were found to be acceptable when used for bearing retention were grouped according to pushout loads and anti-galling characteristics. Galling characteristics have been determined by examination of the surface after pushout and are noted in parenthesis in the figures.

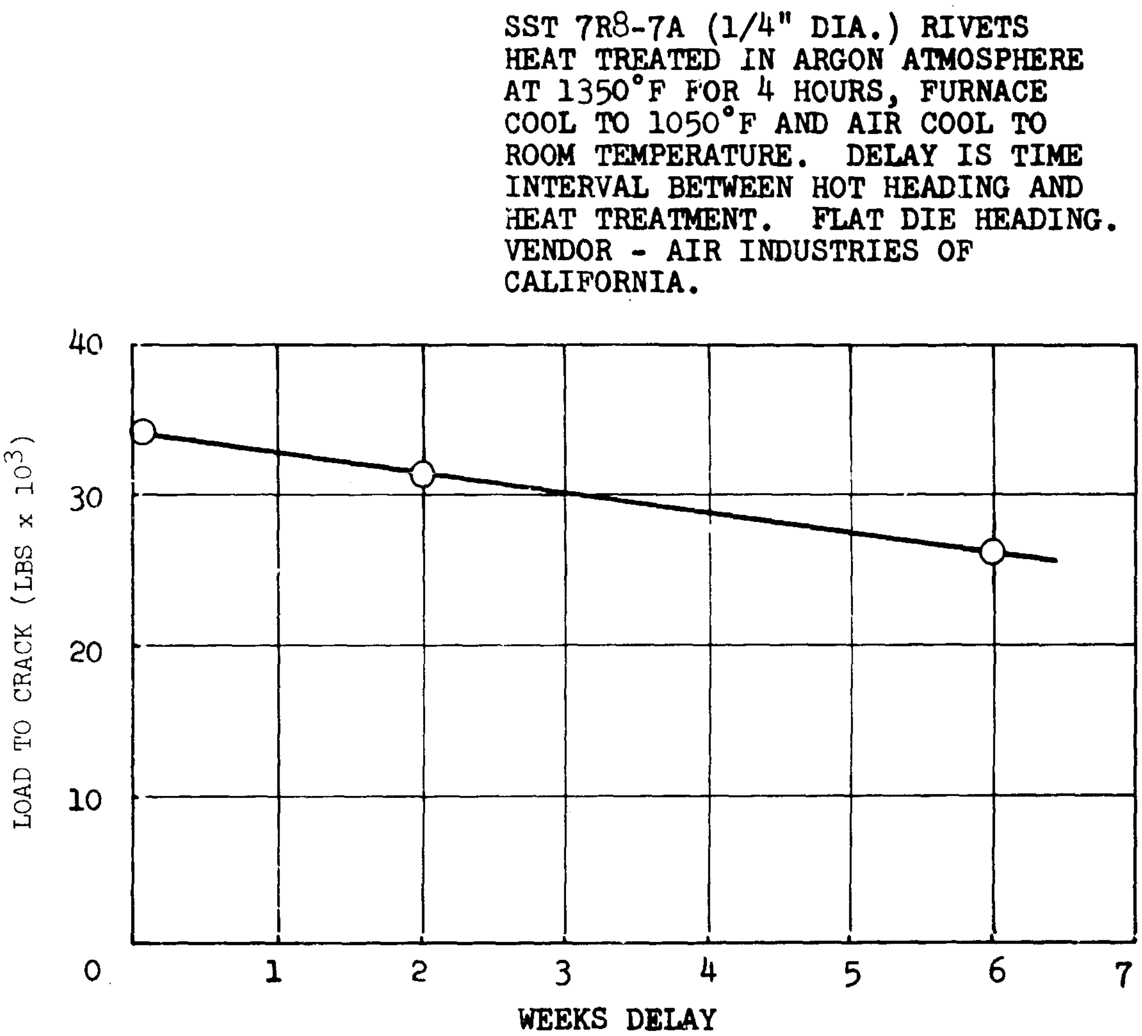


Fig. 12 Heat Treat Study – Ti-6Al-4V Rivets

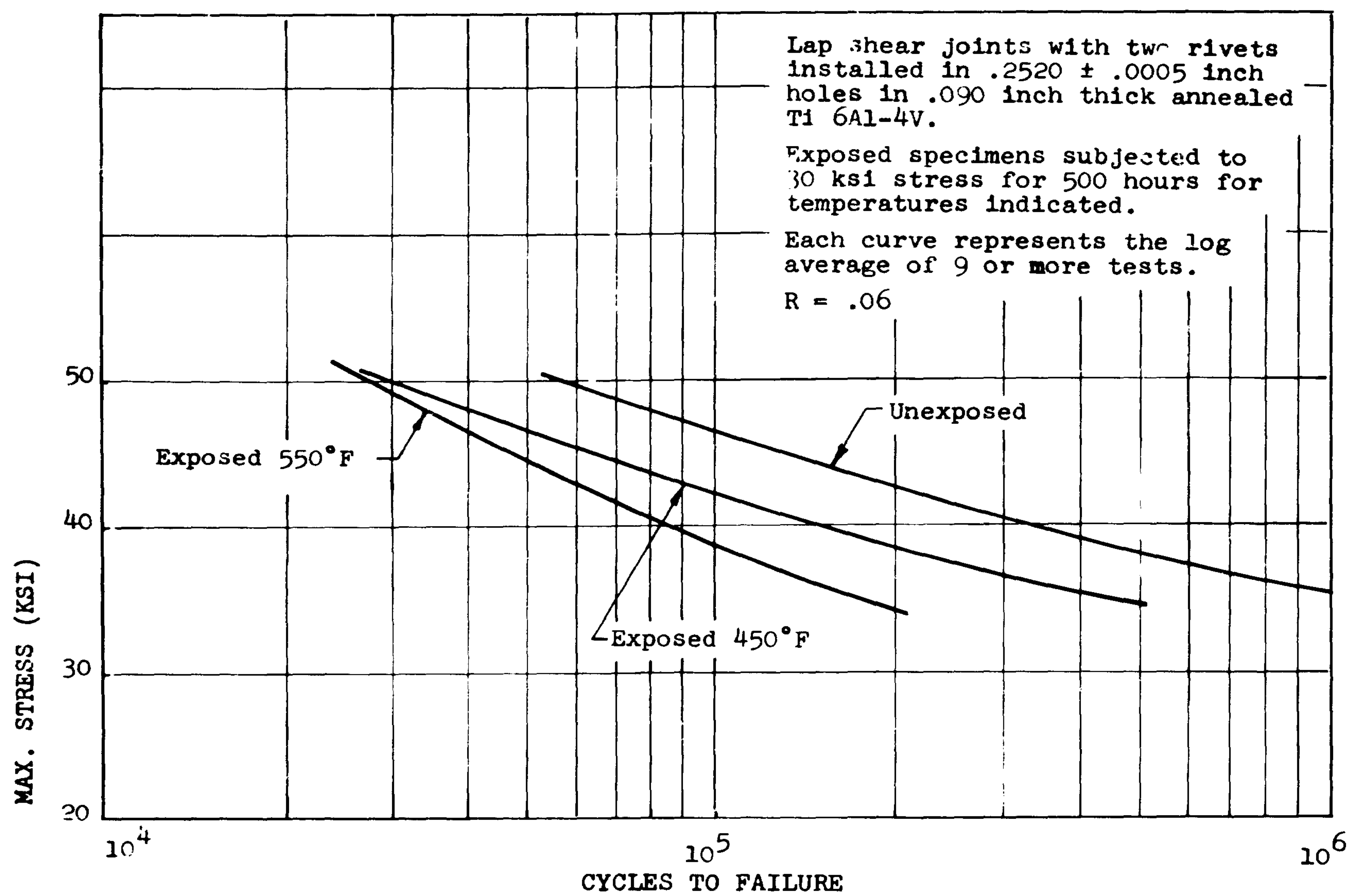


Fig. 13 Exposure Study – A286 Rivets, 32,000 LB Universal Die Heading

Table A Bolt Evaluation Test Results

Bolt Material [1]	Exposure Temperature [2]	Maximum Fatigue Load (R = .1)(pounds)	Cycles to Failure	Log Average Cycles to Failure
Ti 6Al-4V	Room	3200	81,000 153,000 28,000 65,000	68,910
Ti 6Al-4V	500°F	3200	67,000 16,000 64,000 73,000	47,300
Ti 7Al-12Zr	Room	2750	1,000,000 [3] 1,000,000 [3] 919,000 229,000	Greater than 677,300
Ti 7Al-12Zr	500°F	2750	1,000,000 [3] 1,000,000 [3] 229,000 1,000,000 [3]	Greater than 691,800

[1] **Bolt configuration was NAS 1271 with MIL-S-8879 threads**

[2] **Bolts exposed at 500°F were tensile loaded to 50% of 500°F UTS**

[3] **No failure at 1,000,000 cycles**

1008. Materials and Processes (continued)

Test data shown in Figs. 14 through 17 show pushout load plotted against the amount of interference and relative anti-galling characteristics.

The coatings which appeared most promising were Watervliet hardcoat, Lubeco No. 2123, hard chrome plated 17-4PH ring, and flame sprayed titanium oxide. All coatings tested, except Watervliet hardcoat can be applied to the 17-4PH bearing during bearing manufacture thus eliminating the need for coating at bearing installation.

Further tests are planned before final coating selection is made.

Wing Pivot 2-Inch Bearing Program

The test results shown in Table B, on 2-in. bore Teflon woven fabric journal bearings, have been obtained since the July report. Of particular interest is the excellent wear life of specimen No. 201 which was heat-soaked for 10,000 hours at 300°F prior to test.

Teflon-Fiberglass Bearings Vibration Test

Testing has been initiated to determine the performance of Teflon-fiberglass bearings under fluctuating unidirectional and reverse load conditions on 2-inch diameter bearings.

A test fixture has been designed and is operating which subjects the bearings to variable load conditions while oscillating the bearing at temperatures to 450°F. Load, torque, and temperature are continually monitored during the test. The machine has the capability for programming loads to simulate "flying" the bearing for a given set of load conditions. The test machine is shown in Fig. 18. The initial test bushing (using Epon 957 adhesive) has been subjected to the following test conditions and has yet to fail:

Test Temperature	450°F
Sinusoidal Load	10 ± 2 kips
Load Frequency	10 cps
Oscillation Angle	± 30°
Oscillation Rate	22 cpm
Total Load Cycles	70,619
Total Oscillatory Cycles	3,398
Coefficient of Friction	0.0207 at 450°F

Subsequent to the above testing the load was changed to 7 ± 5 kips at 19 cps. The performance of the bearing under this load condition to date is as follows:

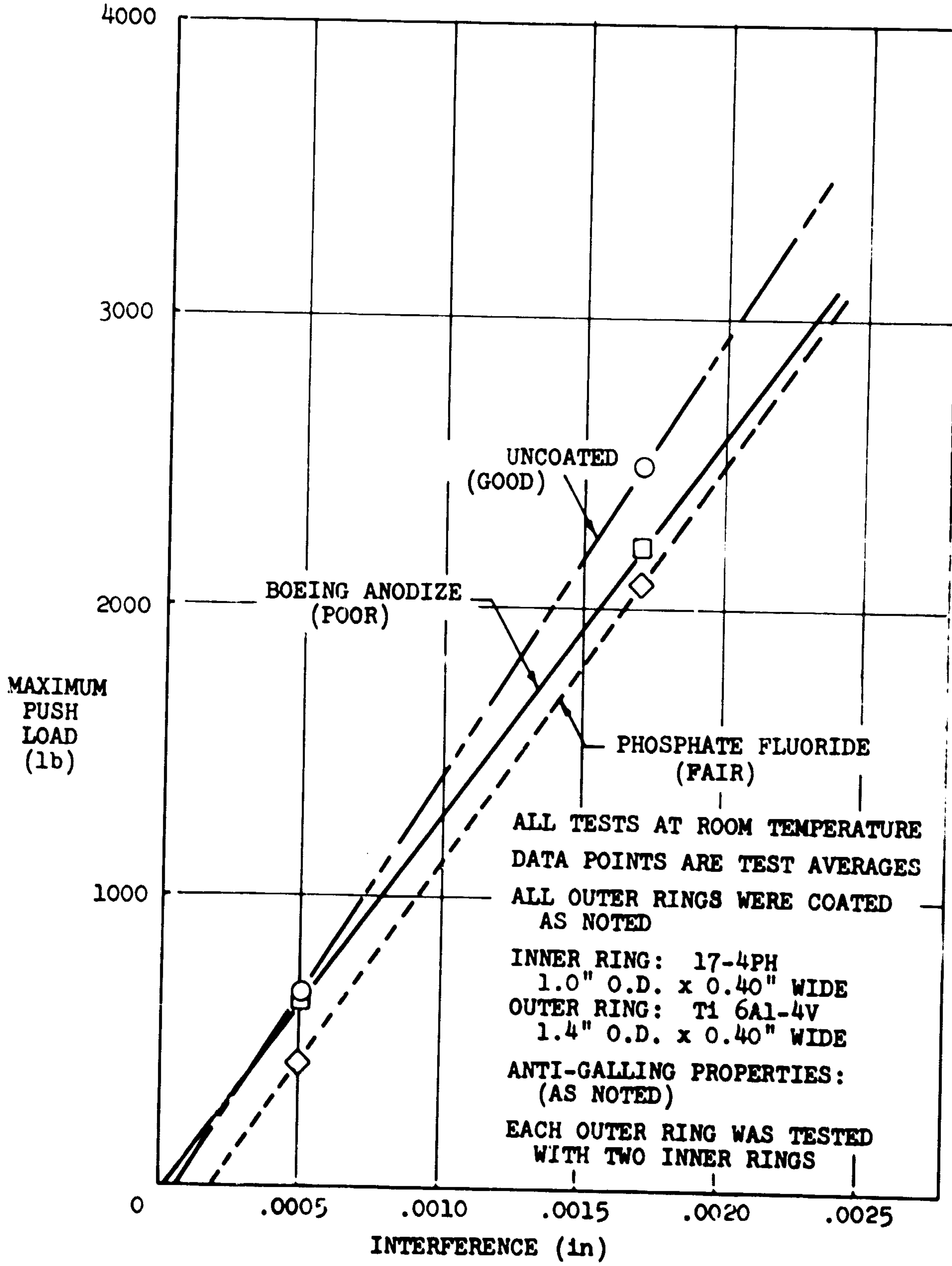


Fig. 14 Bearing Retention, Coating Study

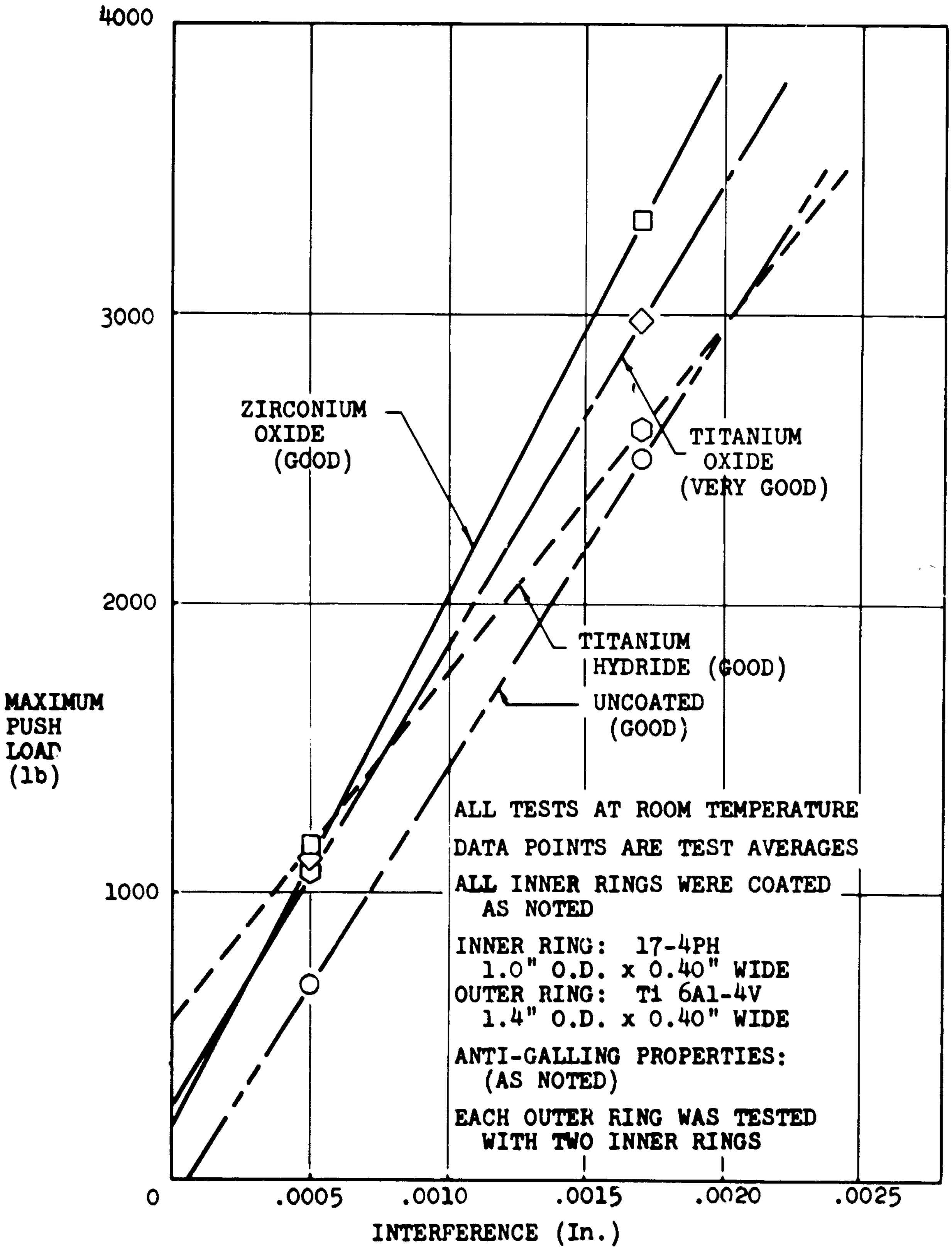


Fig. 15 Bearing Retention, Coating Study

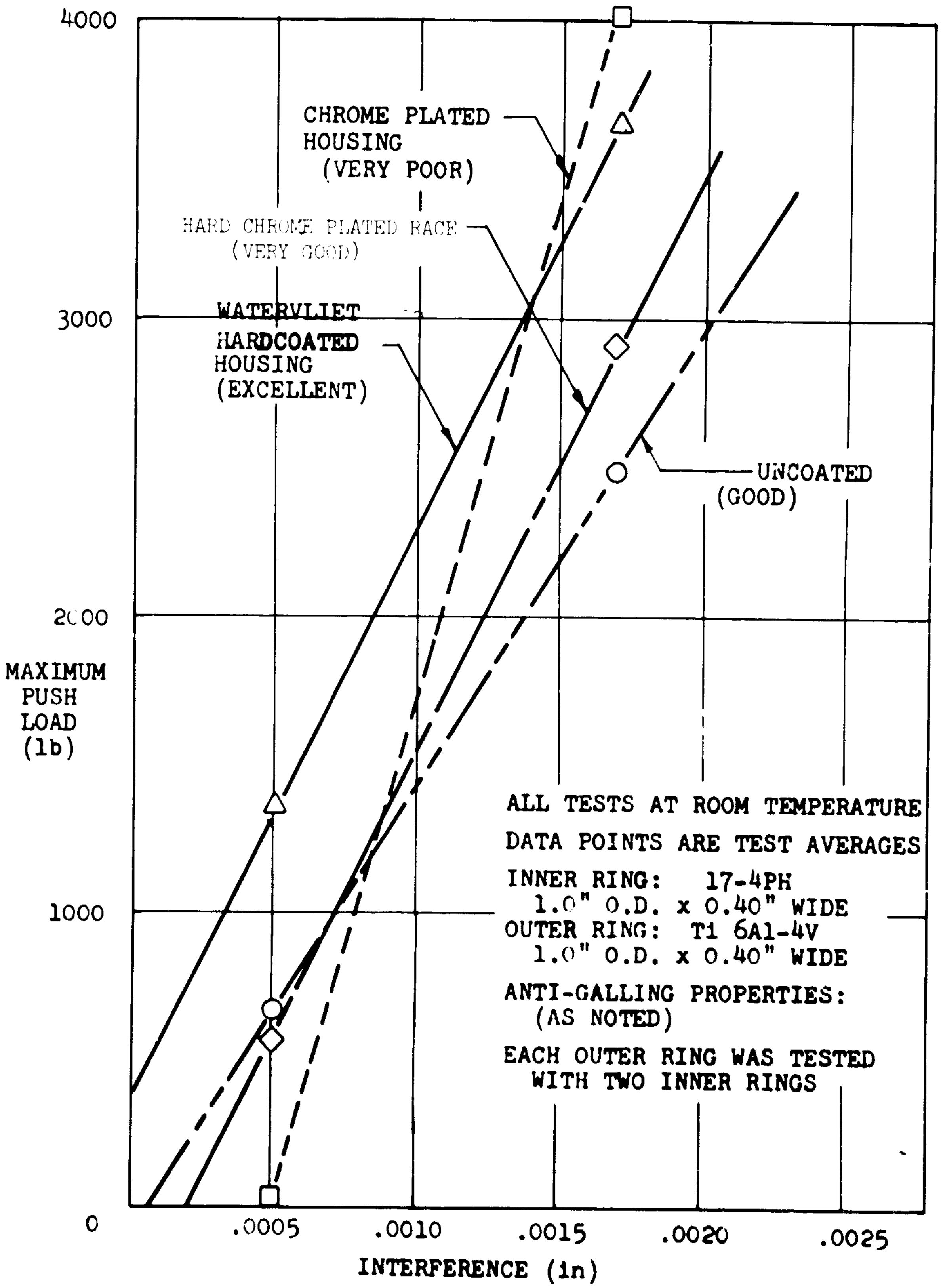


Fig. 16 Bearing Retention, Coating Study

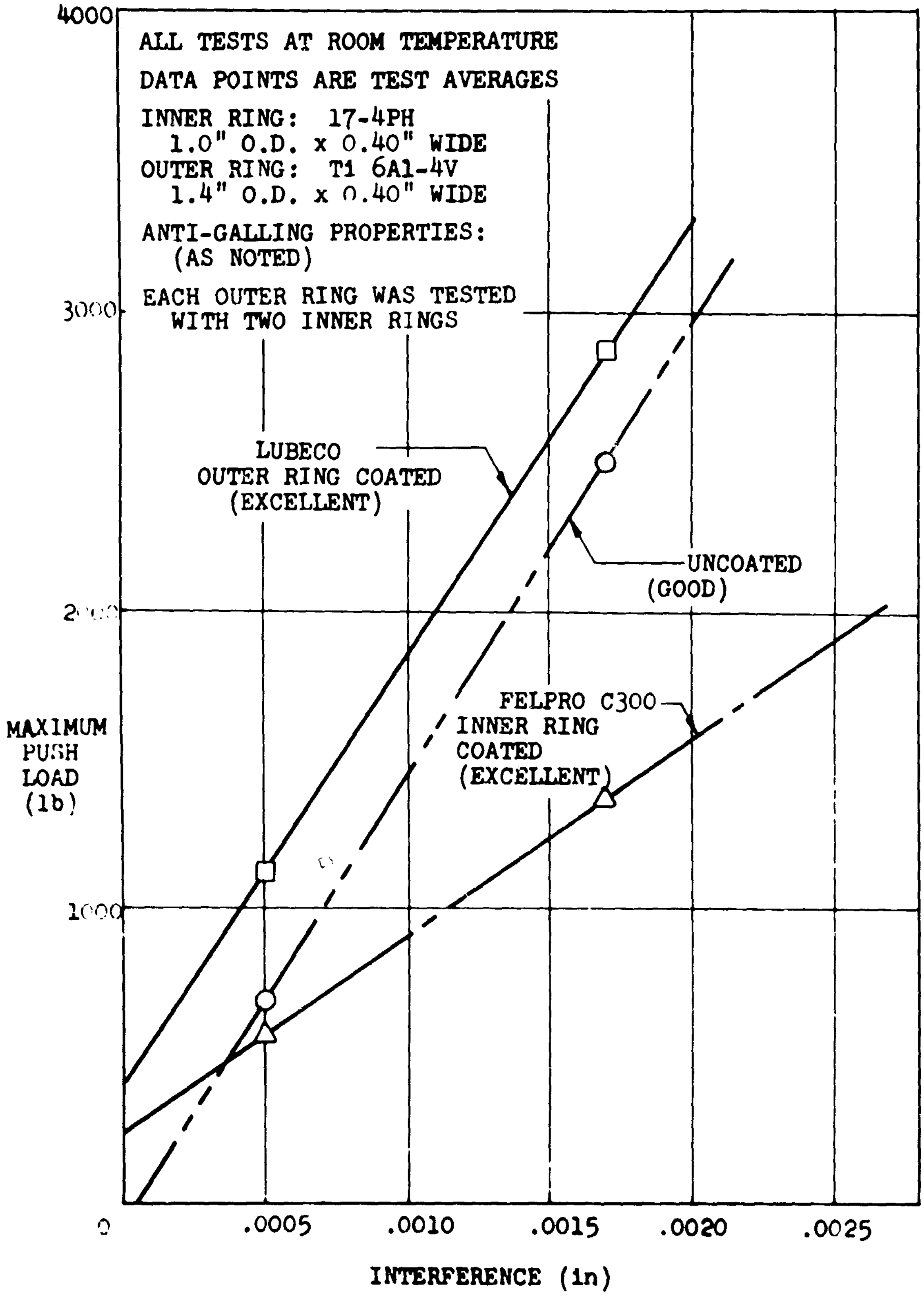


Fig. 17 Bearing Retention, Coating Study

Table B Wing Pivot Bearing Tests

Specimen Number	Load (ksi)	Temp (°F)	Soak Fluid Used Prior To Test	Prior Soak Conditions	Adhesive Used	Bondline Thickness (Mils)	Wear Life [5]	
							Cycles	Feet
298	20	300	JP5 Fuel	[1]	Epon 957	14.1	554,126	107,000
339 [2]	20	300	None		Epon 957	9.3	14,616	2,880
325 [3]	20	300	None		Dyflon	17.7	19,075	3,660
314B	20	300	Heat Only	500 hrs @ 300°F	Epon 957	14.9	940,664	136,000
315	20	300	" "	" "	" "	15.1	584,510	115,000
326	20	300	" "	1000 hrs @ 300°F	" "	14.9	336,007	65,400
307 [2]	20	300	" "	" "	" "	14.8	167,553	32,200
308 [3]	20	300	" "	" "	Reichold A5900	14.3	29,397	5,650
324 [3]	20	300	" "	" "	Dyflon	16.5	117,035	22,500
329B	20	300	" "	" "	FXM-34B-34 Polyimide	13.5	19,557	3,800
328	20	300	" "	" "	"	13.5	40,125	7,796
329	20	300	" "	" "	"	13.0	123,517	24,000
201	20	300	" "	10,000 hrs @ 300°F	Epon 957	12.3	290,245	54,798
316	20	400	" "	500 hrs @ 400°F	Epon 957	14.5	20,055	3,930
316B	20	400	" "	" "		14.5	42,968	8,417
317	20	400	" "	" "	" "	15.1	149,137	26,472
319	20	400	" "	" "	FXM-343-34 Polyimide	12.8	69,394	13,622
333	20	400	" "	1000 hrs @ 400°F	"	13.0	64,000	12,400
332	20	400	" "	" "	"	13.3	73,266	14,100
321	10	450	" "	500 hrs @ 450°F	Epon 957	15.7	107,140	20,900
320	10	450	" "	" "	" "	14.7	1,037,604	201,000
322	10	450	" "	" "	FXM-34B-34	13.5	161,835	31,606
323	10	450	" "	" "	" "	13.2	25,400	4,950
323B	10	450	" "	" "	" "	13.2	21,500	4,200
335	10	450	" "	1000 hrs @ 450°F	Epon 957	15.1	62,563	12,000
336	10	450	" "	" "	FXM-34B-34	13.5	96,767	16,857
337	10	450	" "	" "	" "	13.2	93,022	17,900

[1] Soaked for 22 Hrs. @ Room Temperature then dried for 2 Hrs. @ 300°F. Cycle repeated 10 times

[2] Manufactured by Industrial Tectonics Inc., Compton, Calif.

[3] Manufactured by Southwest Products Co., Monrovia, Calif.

[4] Manufactured by Rex Chainbelt Co. Bearing Div., Downers Grove, Illinois

[5] Failure occurs when shaft wears through fabric-adhesive liner to metal ring.

D-[illegible]

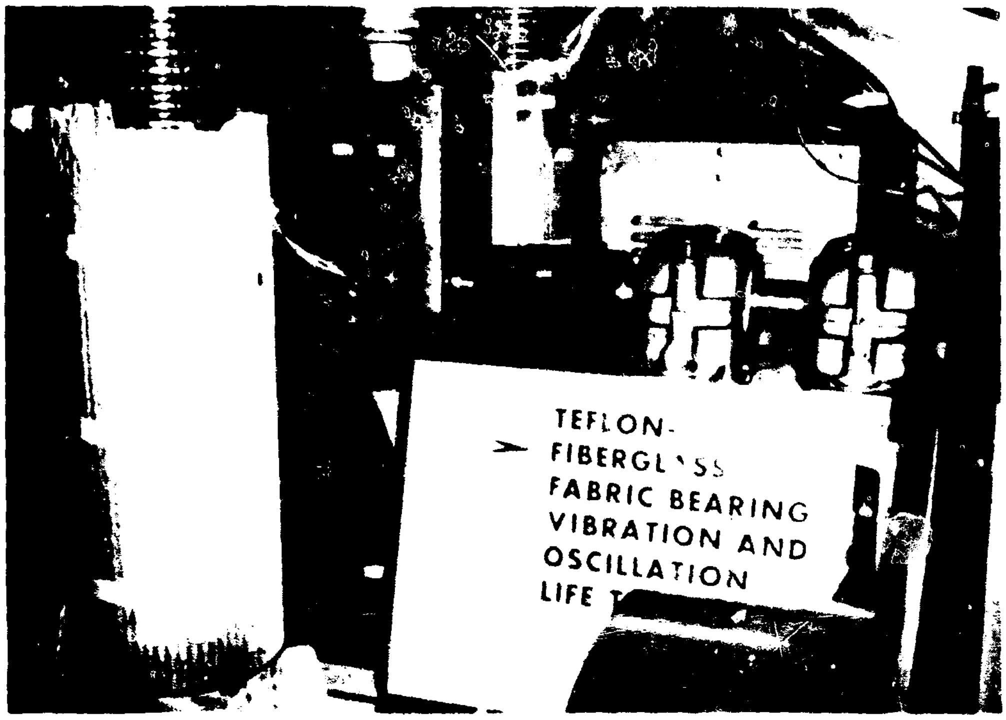


Figure 18. Teflong-Fiberglass Fabric Bearing

III. Description of Technical Progress (continued)

1008. Materials and Processes (continued)

Total Load Cycles	4.6×10^6 Cycles
Total Oscillatory Cycles	92,229 Cycles
Coefficient of Friction	0.014 at 450°F
Total Clearance	0.0062 In.

Testing will continue until a total clearance of 0.010 in. or a friction coefficient of 0.1 is obtained.

Additional testing is also planned at various loads, frequencies, and temperatures.

Track Roller Tests

The Torrington Company of Torrington, Conn. has conducted six track roller tests under the direction of Boeing personnel. The tests were conducted using a Torrington 14NBF1832YJ bearing with AISI 52100 steel races and rollers. The test conditions were as follows:

Test Temperature	400°F
Applied Load	8,000 Pounds
Track Stroke Length	6.28 In.
Bearing Rotation Rate	23.4 rpm

The test results are as follows:

Grease Designation	Manufacturer	Cycles to Failure at 400°F
Royco 60	Royal Engineering Co.	36,626
Royco 60	Royal Engineering Co.	23,610
Royco 60	Royal Engineering Co.	19,990
DC 4-3025	Dow Corning	16,836
EG-551	Marlin Rockwell Corp.	75,858
PR-240AC	DuPont	91,822

The Torrington test machine is being modified to include a 30-in. stroke and a time-load and temperature program to 450°F. Bearings with races and rollers of AMS 5630 (AISI-440C) stabilized steel and Teflon seals are being fabricated for test.

Bauschinger Effect

Tensile specimens were plastically strained 2 percent and 4 percent at room temperature. Three compression specimens were subsequently removed transverse to the strain direction and tested in compression at room temperature.

No apparent change in the compressive yield strength was noted (Fig. 19). However, examination of the stress strain curves showed approximately 50 percent reduction in the proportional limit (Fig. 20).

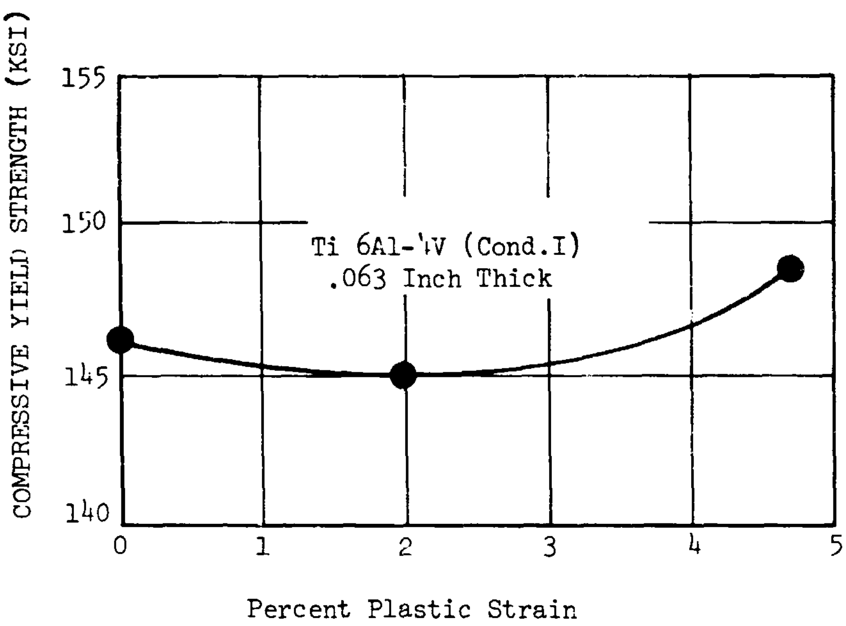


Figure 19. Compressive Yield Strength Versus Percent Plastic Strain

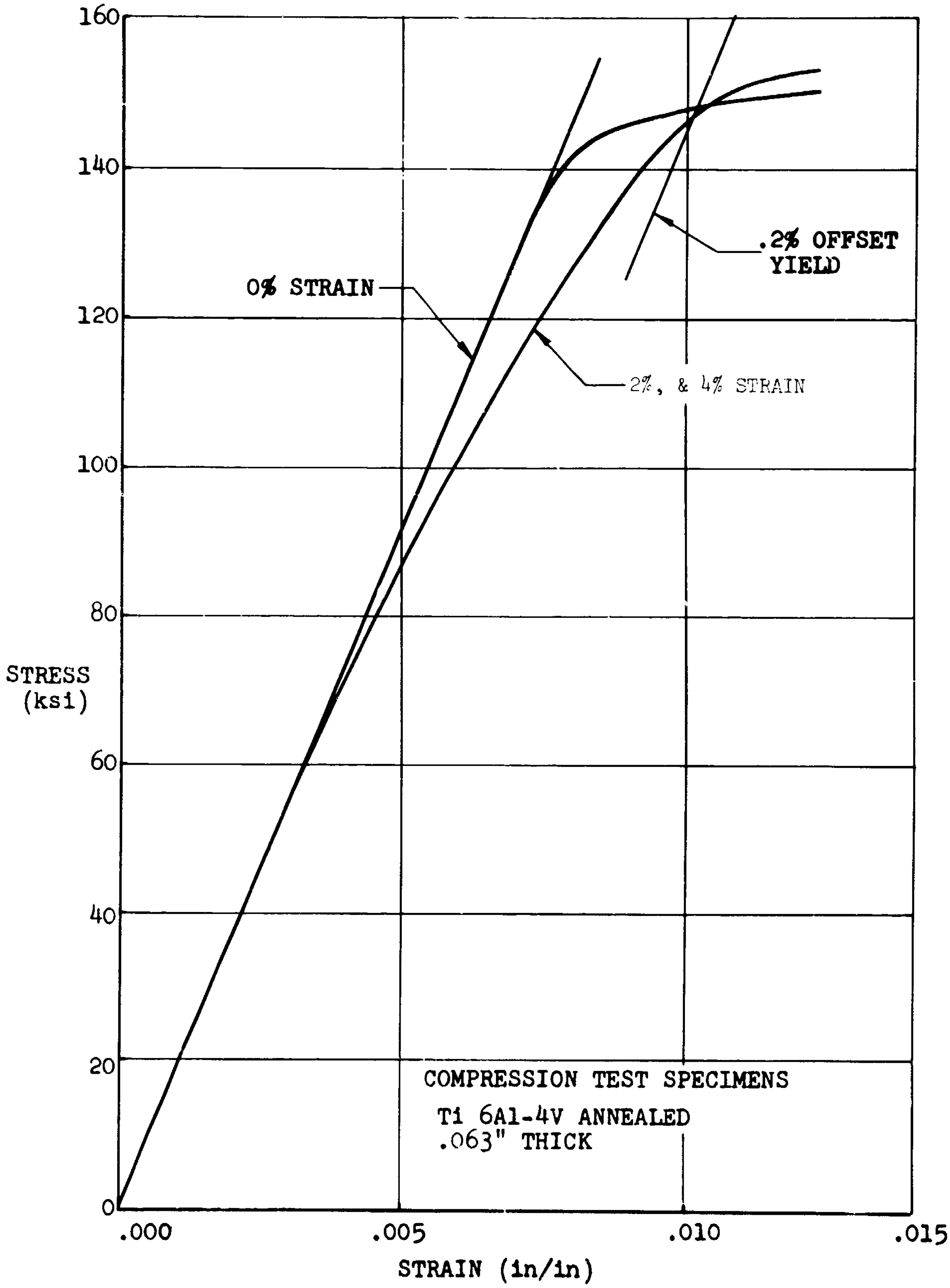


Fig. 20 Stress Strain Curves for Transverse Bauschinger Effect

Further work is being undertaken to substantiate the data and to further evaluate and understand the phenomena. Compression tests on formed sections are being tested to determine the significance of this effect in structure such as, channels and "Z" Sections.

Thermal Cutting of Metals

For thermal cutting, the primary factor to be determined for each thickness and cutting technique is the "Edge Machining Allowance" (EMA), the minimum material thickness which must be removed after cutting. The EMA is presently being determined by microhardness traverses and metallurgical examination.

Several specimens of Ti 6Al-4V and Ti 8Al-1Mo-1V varying in thickness from 3/4 to 6-3/4 in. have been thermally cut by three processes: oxyacetogen, oxyacetylene, and plasma arc. Metallographic samples from these specimens are being prepared.

Initial results indicate that the plasma arc process is most efficient for thicknesses to 1-1/2 in. Although 4-in. material has been cut with this equipment, it produces a large kerf width and excessively furrowed surface.

Titanium alloy Ti 6Al-4V, 5-3/4 in. thick, can be readily cut with oxyacetylene. The heat-affected zone (HAZ) is less than 1/16-in. for the entire length of cut. However, an EMA of about 1/4-in. would be required to compensate for the beveling effect on the top surface. Another 5-3/4-in. thick specimen measuring about 3/4-in. wide was cut with oxyacetylene. The low heat sink of this narrow specimen caused considerable reddening of the metal during cutting. The HAZ was only 1/8-in. thick, but an EMA of about 1/2-in. would be necessary to compensate for the top surface bevel.

A few cuts with oxyacetogen indicate that this process leaves a cleaner smoother kerf than oxyacetylene. The HAZ's of these processes will be determined.

Fusion Welding

Static tensile test results for dual, gas-shielded tungsten arc weldments in four 0.25-in. thick titanium alloys are summarized in Table C.

Residual Stresses in Titanium

Fatigue tests have been conducted on as-fusion-welded and welded-plus-thermally stress-relieved panels of 0.250-in.-thick Ti 6Al-4V. The welds were longitudinal with the weld bead removed. The surfaces were lightly shot peened to prevent surface induced failures. The data shown in Table D indicate the stress relieved welds have improved fatigue life compared to as-welded specimens. This difference is attributed to the residual welding stress.

Table C Static Tensile Test Results of DGTA Welded 0.250 Thick Material

Titanium Alloy	Specimen Type [2]	Average Ultimate Stress (ksi)	Average Tensile Yield Stress (ksi)	% Elongation	
				1"	2"
8Al-1Mo-1V	Base Metal	144.8	128.2	----	16.1
	Long. Weld	144.5	124.3	14.6	----
	Transv. Weld	143.8	134.3	----	15.1
6Al-4V	Base Metal	146.2	140.9	20.4	15
	Long. Weld	142.1	133.0	12.5	9
	Transv. Weld	149.2	143.8	16	11
4Al-3Mo-1V	Base Metal	138.5	124.7	17	11.3
	Long. Weld	146.5	130.8	4.6	3.2
	Transv. Weld	136.4	127	0.4	2.4 [1]
5Al-3Mo-1V-2Sn	Base Metal	150.5	145.8	13	----
	Long. Weld	158.1	147.3	8	----
	Transv. Weld	155.1	149.8	5.6	----

[1] Failed outside of 2" gage length.

[2] Specimens per Dwg. D6-4671-104.
No filler addition was used.

1008. Materials and Processes (continued)

Longitudinally welded tensile coupons were processed along with the fatigue specimens. The results given in Table E show a slight improvement in tensile yield strength and no significant change in ultimate strength. All of the specimens were from the same sheet of 0.250-in.-thick material.

Fatigue tests have been conducted on two-spot, in-line lap-shear resistance welded specimens in as-welded, thermally stress relieved, and impact stress relieved conditions. The specimens were all welded within a period of four hours using the same machine, and then randomly divided into three groups for further treatment. The data given in Table F show that impact stress relief results in an increase in fatigue life. The thermal stress relief reduced fatigue life slightly. All specimens were 2-inch wide from the same sheet of 0.250-in.-thick Ti 6Al-4V.

Document D6A10075-1, "Residual Stress in Titanium, Part I," has been released.

Minimum Bend Radius and Springback

Minimum bend radius and springback were determined for solution treated, solution treated and aged, and annealed Ti 6Al-4V per Boeing document D2-4064.

Figure 20 shows minimum bend radius as a function of material thickness. At room temperature the minimum bend radius (R/t) varies from 5 for 0.020-in.-thick material to 4 for 0.125-in.-thick material. At 1150°F an improvement of about 1-1/2 in. R/t is noted. However, this improvement is similar to that noted for room temperature forming when using a urethane pad lower die. At room temperature the springback varied from 28 degrees with 0.020-in.-thick material to 16 degrees in 0.125-in.-thick material (see Fig. 21). At 1150°F springback was reduced to about 16 degrees in 0.020-in.-thick to 12 degrees in 0.125-in.-thick material. Using urethane for the lower die the springback from room temperature forming was similar to that obtained for 1150°F forming in steel dies. Figure 22 shows the variation in 0.020-in., 0.060-in., and 0.125-in.-thick material with temperature. Singular data points for different heat treat conditions are included. It is seen that as test temperature increases, the springback varies little until higher temperatures (800°F) are reached, at which time springback drops off and approaches zero degrees at 1400°F.

Work is continuing on the evaluation of forming characteristics of Ti 6Al-4V on Conditions I, II, and IV. Extensive work is being done to evaluate urethane forming as a potential method for small

Table D Effect of Residual Stress on Fatigue Life of Ti-6Al-4V Weldments [1]

Max. Applied Stress [2] (ksi)	Cycles to Failure	
	As-Welded	Stress Relieved [3]
77.5	436,000	1,500,000 NF
	599,000	1,500,000 NF
	753,000	827,000
	274,000	
77.5	1,020,000	

[1] DGTA Weld

[2] R = .06

[3] 1250F, 45 min. AC

Table E Effect of Thermal Stress Relief on the Static Strength of Fusion Welds in Ti-6Al-4V

Condition	Ultimate, Strength (ksi)	.2% Yield Strength (ksi)
As-Welded	151.1	133.4
	150.7	130.9
	151.0	129.8
	146.8	138.9
	147.3	126.7
	148.6	131.1
	152.2	133.3
	150.1	130.0
As-Welded	149.7 (Avg.)	131.8 (Avg)
Stress Relieved	149.2	139.5
	149.5	139.4
	149.6	139.8
	151.7	137.3
	151.1	137.6
	152.6	141.6
	148.4	129.4
Stress Relieved	150.3 (Avg.)	137.3 (Avg.)

Table F Effects of Stress Relief on the Fatigue Life of Resistance Spotwelded Specimens 1

Cycles to Failure @ 10 ksi Max. Stress Level, R = .06		
As-Welded	Thermal Stress Relief 2	Impact Stress Relief 3
130,000	87,000	581,000
127,000	77,000	561,000
125,000	127,000	1,136,000
138,000	105,000	1,261,000
11[illegible],000	102,000	872,000
108,000	134,000	
Log Avg. 124,000	103,000	960,000

1 Class A Resistance Weld per BAC 5925

2 1250 F 45 min in Vacuum

3 Impacted with 400 FT-lb, 2" Radiused Anvils

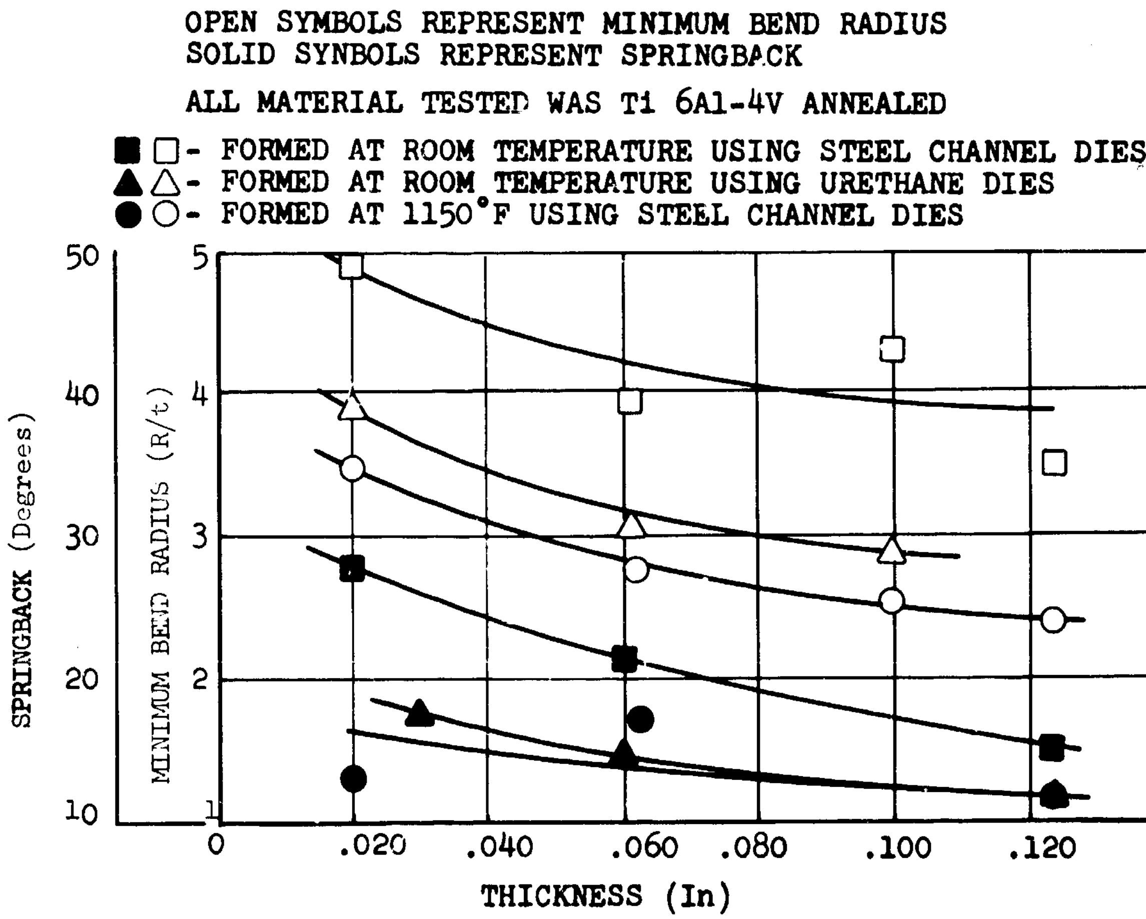


Fig. 21 Minimum Bend Radius Versus Thickness

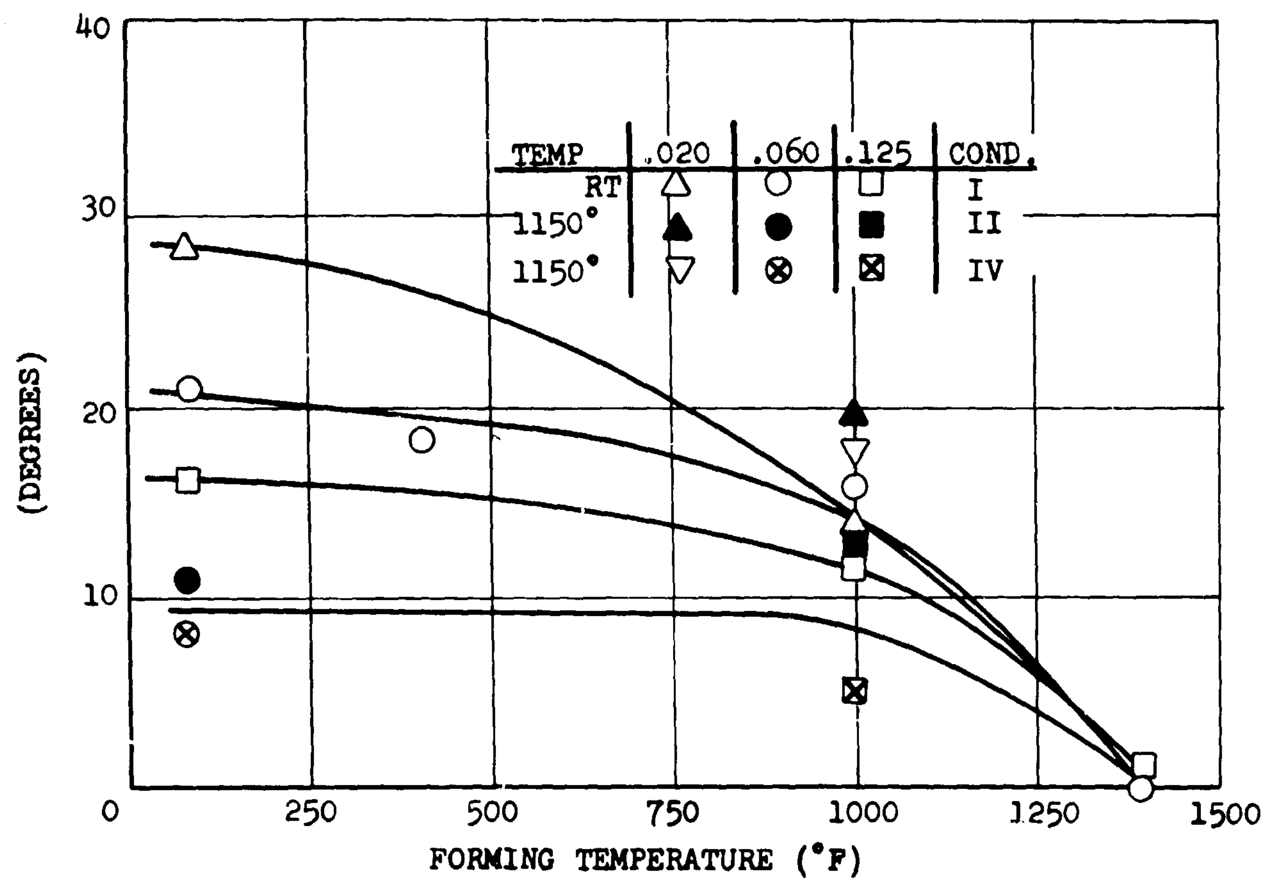


Fig. 22 Springback Versus Forming Temperature Ti-6Al-4V (Cond. I, II, IV) at R/T = 4

1008. Materials and Processes (continued)

parts that would normally have to be hot formed and sized to meet design criteria.

Residual Stress Measurements in Formed Parts

Theoretical calculations have been made of the variation of residual stress with bend radius (Boeing document D6A10075-1). To verify this, bend specimens were made from one test of 0.050-in.-thick Ti 6Al-4V and brake formed to bend radius/thickness ratio of 5, 13.3, 22, 40, 50, and 61. Strain gages were mounted on the tension side (inside) of the bend and the opposing side was etched away. Strain measurements were reduced to stress levels after corrections for bi-axiality were made.

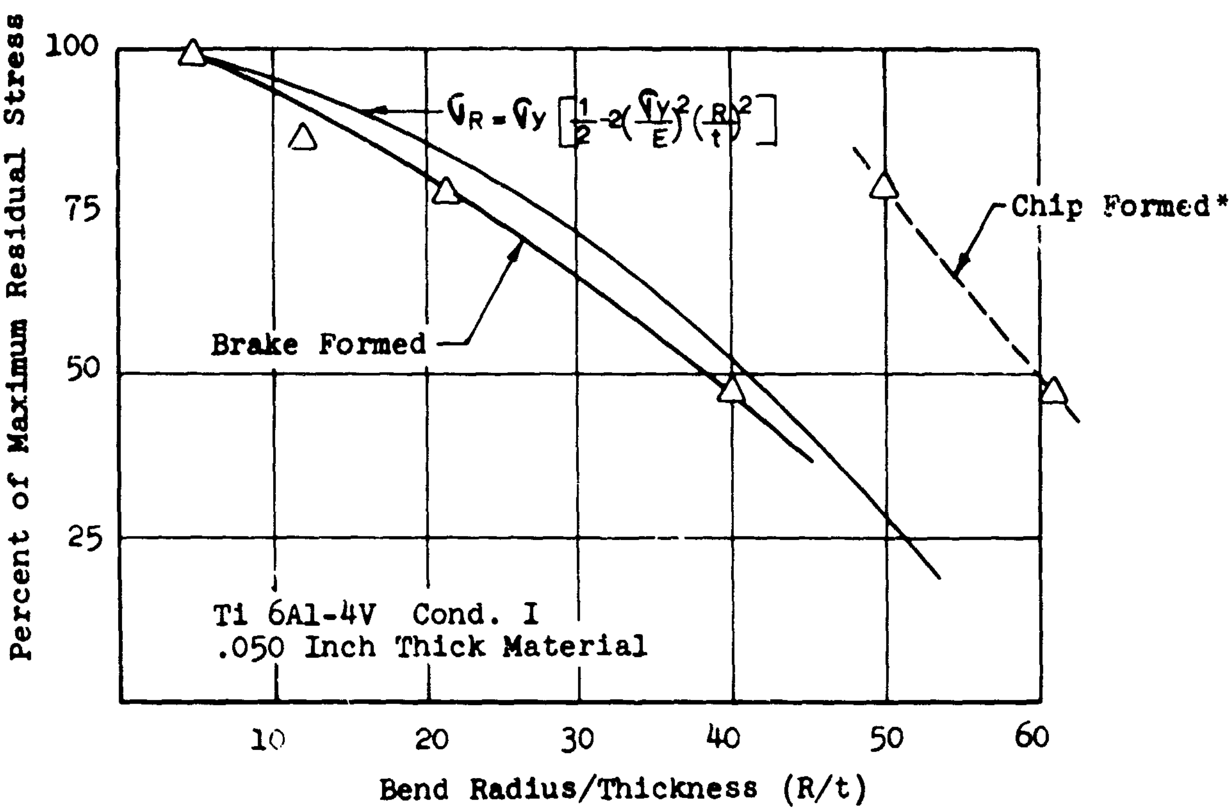
Figure 23 shows that the theoretical calculations and data obtained are in close agreement to an $R/t = 40$. "Chip" forming was required to form the higher bend radii which resulted in substantially higher residual stress levels. Work is continuing to determine how the residual stress level is influenced by chip forming.

1009. Mockups

There has been considerable activity in the mockup area the past two months. The following table summarizes the mockups constructed and the date of their completion:

Mockup	Completion Date
Wing-Body Joint	August 8
P&WA Engine Installation	August 31
GE Engine Installation	August 31
Electrical/Electronics Racks	August 31
Full-Size Airplane	September 6
Accessory Drive & Environmental Control Systems Installation	September 6
Wing Pivot	September 16
Cargo Provisions	September 16

Certain mockups were arranged in the mockup display area to aid in presenting the B-2707 design concept to the U.S. Government on-site evaluation team.



*Radius formed in small increments by brake press

Fig. 23 Residual Stress Versus Bend Radius Thickness

1009. Mockups (continued)

The full-size Class I airplane mockup was the central mockup in the display area. The mockup has a pivoting fuselage forebody, pivoting outboard portions of the wing, and a completely furnished passenger cabin interior. An exterior view of the full-size airplane mockup is shown in Fig. 24, and an interior view is shown in Fig. 25.

1013. Standardization

Fifteen supplier bid proposals have been reviewed by the Standardization Unit during this report period to determine the adequacy of their standardization program.

The first draft of the proposed standardization training document has been prepared. This document will be used for the SST Standardization training of the major subcontractor representatives and all the Boeing engineering staff and designers.

Material and Process Specifications that apply to the SST are continuing to be reviewed for inclusion in SST program documentation.

1016. Human Engineering

The document D6A10252-1, "Evaluation of B-2707 - SST Visual Fields in Cruise on a Visual Flight Simulator," was approved and released. Study results indicate windshield configurations offering more forward vision are rated high in pilot acceptance. Also, study results indicate that visual orientation, particularly pitch reference and attitude control are enhanced by windshields and windows that align with the horizon. The results of this study were used in the design of the proposed B-2707 windshield.

Human Engineering data analysis and document preparation of the simulation study, "Evaluation of B-2707 - SST Visual Field by Simulated Cruise and Landing," D6A10252-2, was approved and released. Study results show that pilot visual performance using the selected windshield configuration was rated satisfactory in normal approach and landing.

The document D6A10254-1, "SST Vision Studies - Light Transmission, Reflections, and Glare," was approved and released. Study results indicate that the quality of vision provided by the windshield for daytime operations is adequate with respect to study parameters. Nighttime vision is adequate; however, excessive pilot attention is required during flight because of reductions in apparent contrast and object detection capabilities.

The radiation study, D6A10424-1, "A Definition of the SST Cosmic Radiation Environment," was completed, approved, and released.

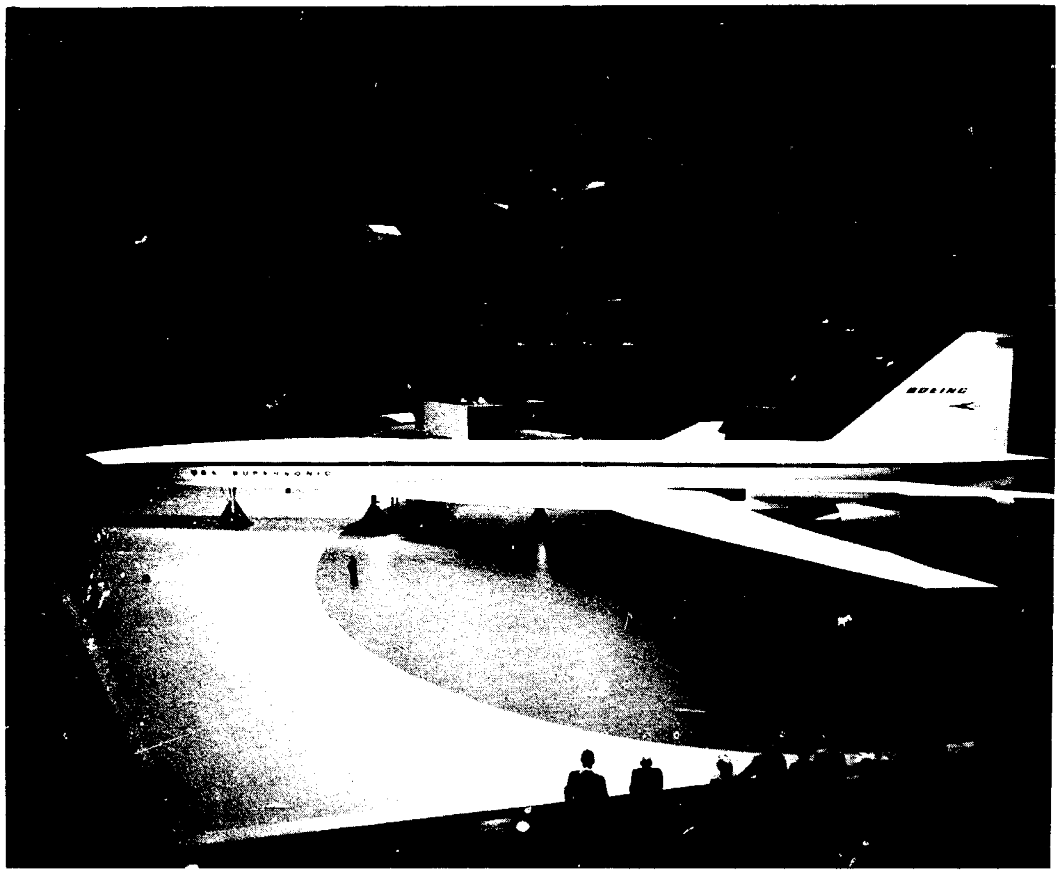


Fig. 24 Full-Size Airplane Mockup

Fig. 25 Interior, Full-Size Airplane Mockup

1016. Human Engineering (continued)

Study results show that galactic cosmic radiation is not expected to be a serious consideration. Solar flares, however, are unpredictable, and rare, but significant, exposure events may be encountered. As a consequence of this study, a solar and galactic radiation detection and monitoring device has been incorporated into the SST design.

The preliminary SST Task Analysis, the Workload Analysis, and the Equipment Analysis, have been completed and incorporated into the document D6A10280-1, "SST Flight Deck Crew Tasks and Equipment Analysis."

11. AIRFRAME STRUCTURE

1100. Airframe Structure – General

11001. TITANIUM ALLOY DEVELOPMENT

Metallurgical Stability of Ti 6Al-4V and Ti 4Al-3Mo-1V

Test specimen elevated temperature exposures are continuing, for determination of metallurgical stability of Ti 6Al-4V and Ti 4Al-3Mo-1V. The 10,000-hour exposure tensile specimens (Fig. 26) for Beta-STA-1250 (Ti 6Al-4V) and Beta-STA-1150 (Ti 4Al-3Mo-1V) have accumulated 6,749 hours at 450°F under 25 ksi tensile stress. Test blanks for the notch-bend tests in the same conditions have accumulated 7,236 hours at 450°F and 25 ksi tensile stress.

Twelve Beta-STA-1250 Ti 6Al-4V notch-bend specimens containing fusion welds have been exposed for 5,000 hours/25 ksi/450°F. Test results are not yet available.

The first phase of a study to evaluate the fracture properties of Ti 6Al-4V sheet has been completed. The material was heat-treated to the mill and duplex anneal conditions and tested in thicknesses ranging from 0.040-0.125. The fracture toughness values for the two conditions are essentially equivalent for the thicknesses tested (Fig. 26). Both the environmental fatigue crack growth characteristics and the environmental crack growth resistance (stress corrosion) of the duplex annealed material are slightly better than the properties of mill annealed material (Figs. 27, 28, 29). Testing of intermediate thicknesses and additional heats of material is continuing under this program.

11002. HIGH-STRENGTH STEEL EVALUATION

The 5,000 hour stability testing of high-strength steels has been completed. Figure 30 shows the results of the testing. Most of the property changes after exposure were insignificant and within the range of test scatter.

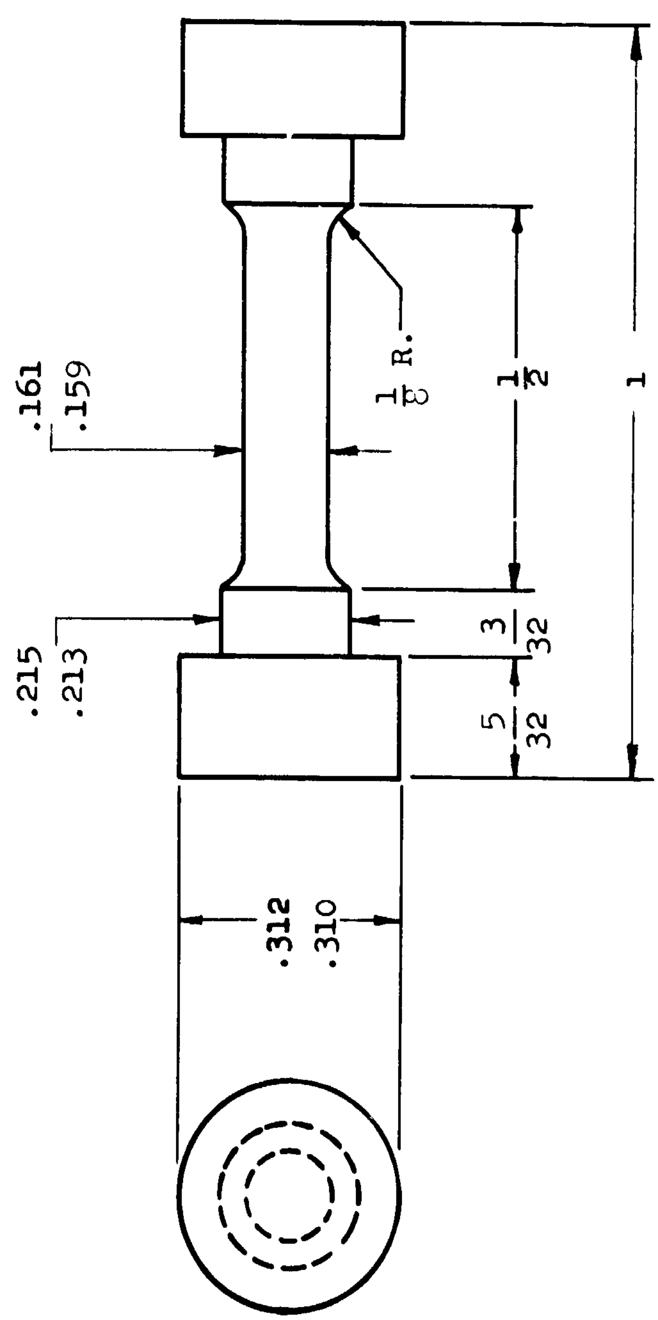


Fig. 26 Tensile Specimen

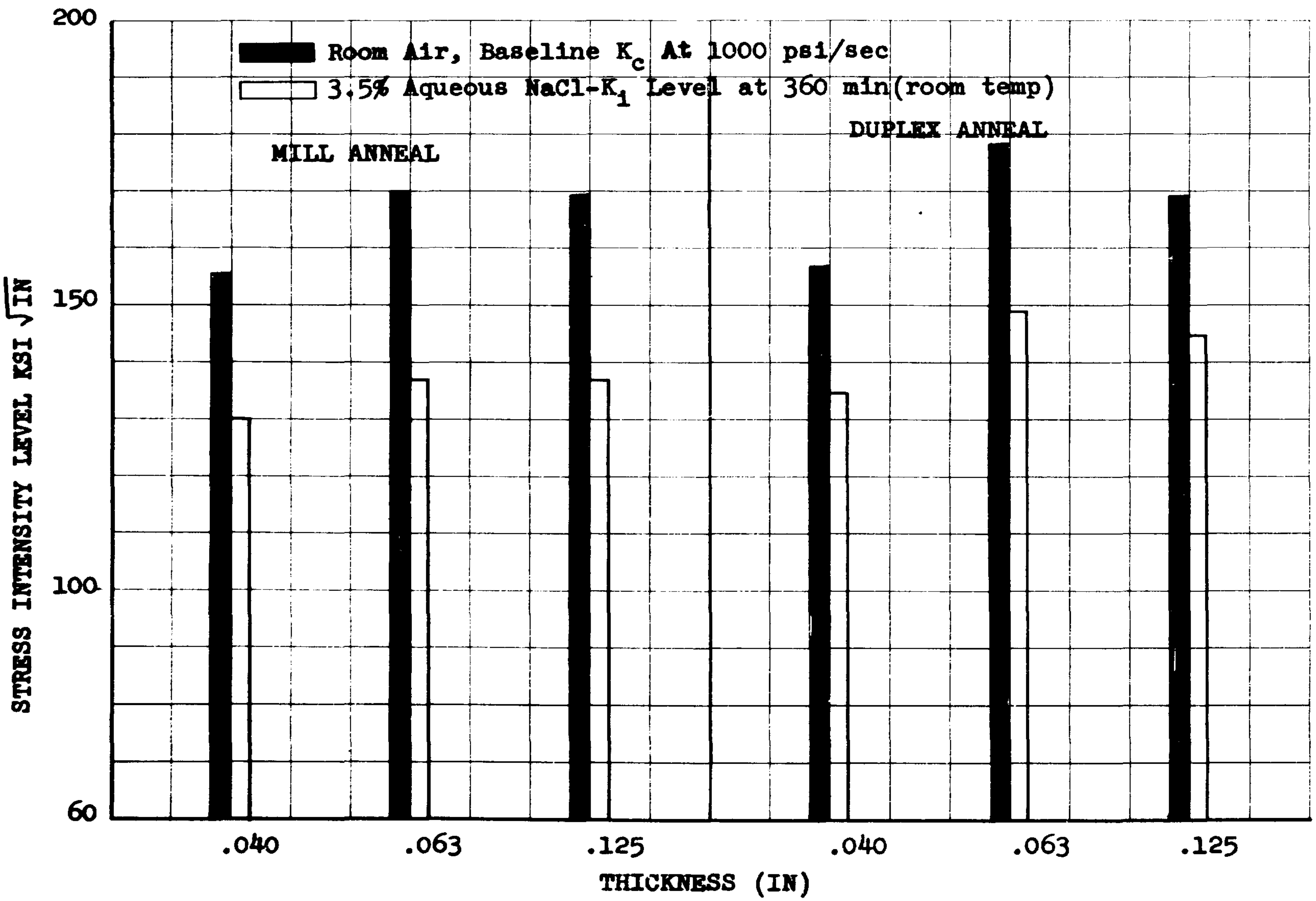


Fig. 27 Comparison of Fracture Properties for Ti-6Al-4V

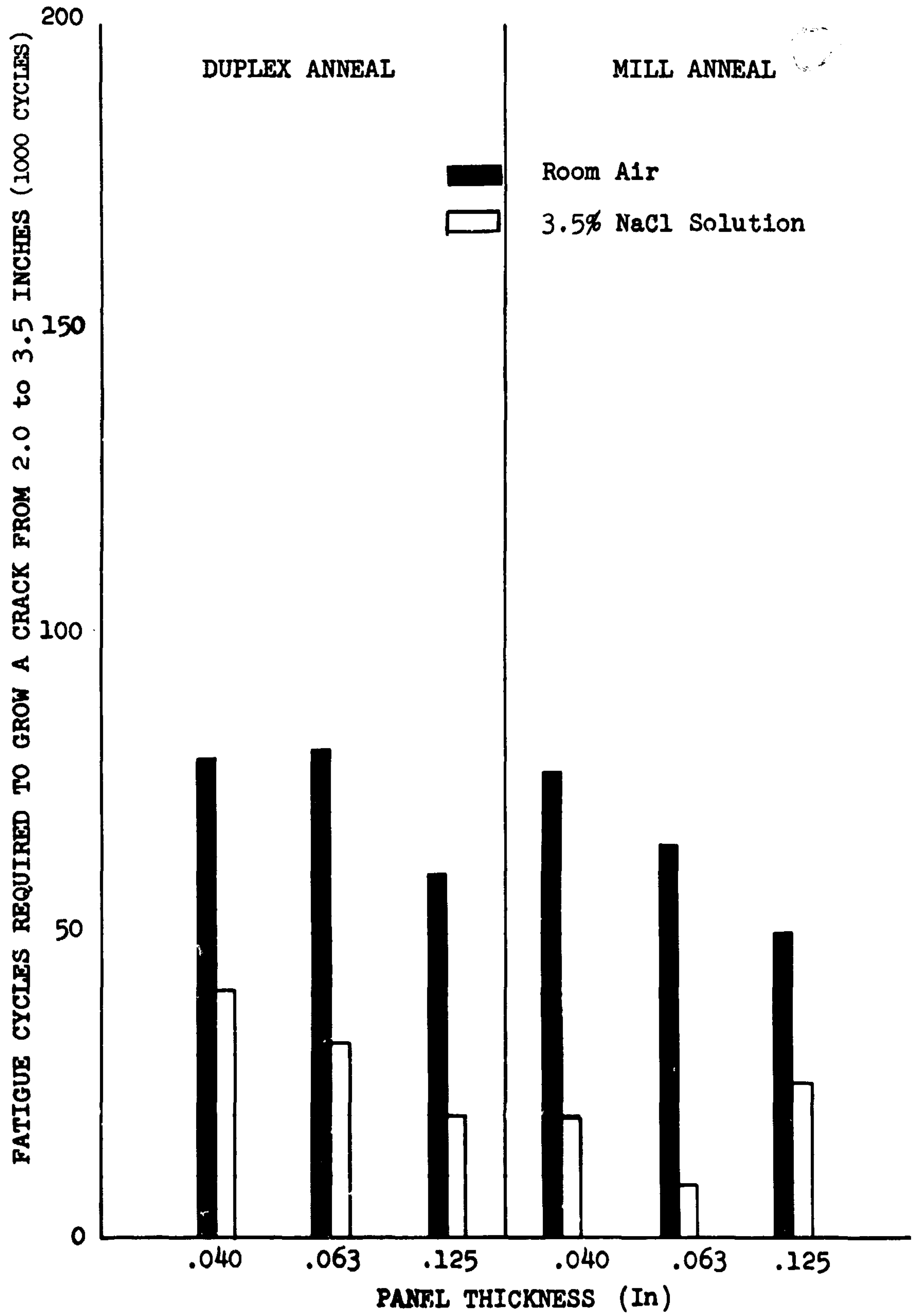


Fig. 28 Comparison of Environmental Fatigue Crack Growth Results for Ti-6Al-4V

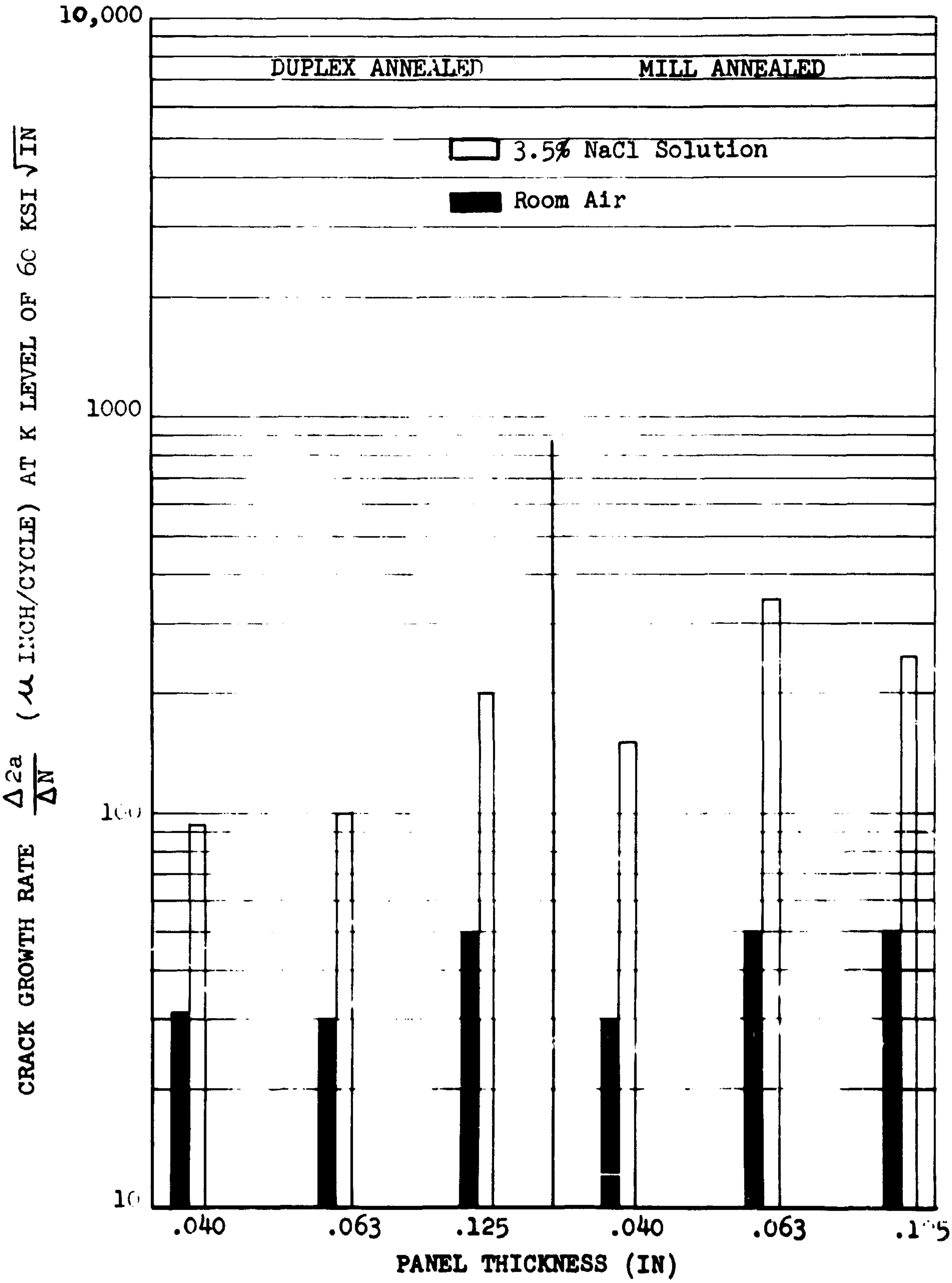


Fig. 29 Comparison of Environmental Fatigue Crack Growth Rate at Constant K Level for Ti-6Al-4V

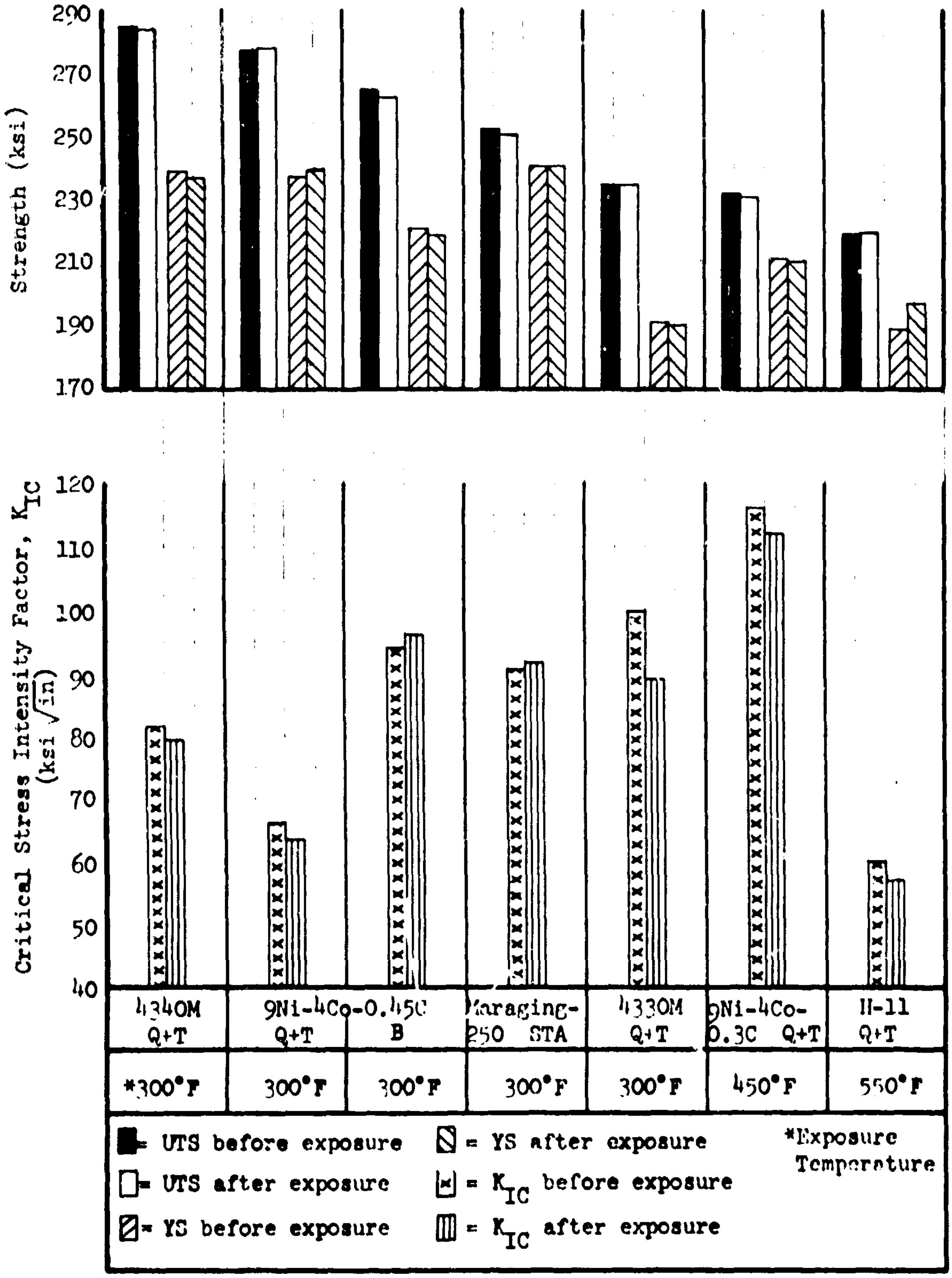


Fig. 30 Effect of 5,000 Hour and 40 ksi Sustained-Load Exposure on Properties of High-Strength Steels

III. Description of Technical Progress (continued)

11002. High-Strength Steel Evaluation (continued)

The results of the salt alternate immersion testing are shown in Fig. 31. These results provide a measure of the relative stress-corrosion susceptibility. According to the results, the least susceptible alloys were 9Ni-4Co-0.30C, Maraging 250, and 9Ni-4Co-0.45C (Bainitically treated).

11003. SANDWICH PANEL SONIC TESTING

Honeycomb panels have been tested using the highest sonic levels anticipated for any SST structure and the test results are tabulated below. These panels have been tested at both room temperature and 450°F. The effect of impact damage to the exterior skin was also investigated. Similar panels are being soaked at a temperature of 450°F and will be sonic tested after completion of several thousand hours exposure.

	Test Sound Pressure Level (Random Noise)	Test Time	
Panel Tested at Room Temperature	160 db	3 hours	No Failures
	165 db	3 hours	
	168 db	3 hours	
	170 db	14 hours	
	171 db	1½ hours	
Panel Tested at 450°F	160 db	3 hours	No Failures
	165 db	3 hours	
	168 db	3 hours	
	170 db	3 hours	
Panel tested with controlled impact damage. Panel was damaged by dropping a 2-in. diameter steel ball from a 6-ft height onto 5 locations on the 0.010 gage titanium outer skin	170 db	2 hours prior to dropping steel ball	
	170 db	3 hours after dropping steel ball - No failure and only minor damage growth at 2 impact locations.	
2 panels damaged by dropping 2-in. diameter ball 4 to 6 ft at one location	170 db	3 hours prior to dropping steel ball	
	170 db	3 hours after dropping steel ball - No damage	

Alloy	Heat Treatment	UTS (ksi)	YS (ksi)
4340M	Quench and Temper	284	235
9Ni-4Co-0.45C	Quench and Temper	274	234
9Ni-4Co-0.45C	Bainitic	265	220
Maraging-250*	Solution Treat and Age	280	272
4330M	Quench and Temper	238	196
9Ni-4Co-0.30C	Quench and Temper	230	201
H-11*	Quench and Temper	224	190

* Data from Report No. ML-TDR-64-3

Indicates that some of the specimens did not fail.

Indicates no failures in 1000 hours.

Unnotched bend specimen

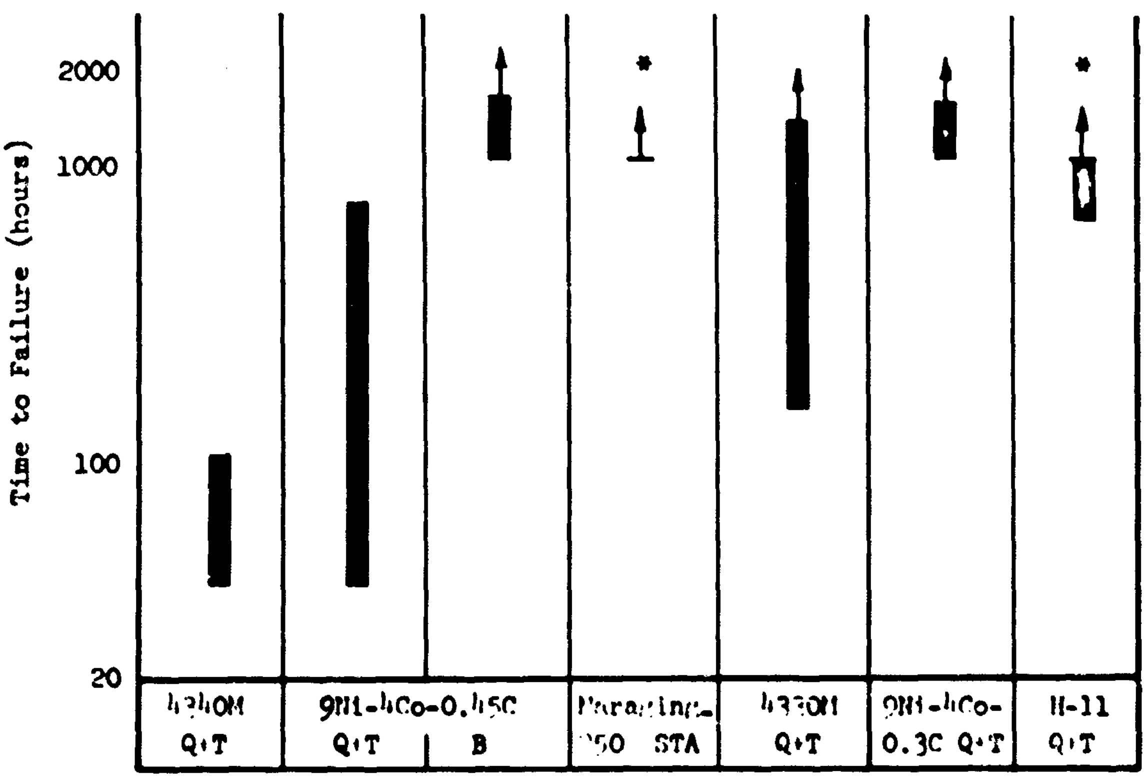


Fig. 31 Relative Stress Corrosion Susceptibility, All Specimens Stressed to 80 Percent of Yield Strength

III. Description of Technical Progress (continued)

11003. Sandwich Panel Sonic Testing (continued)

As an aid in interpretation of these test results, three hours testing at 170 db is estimated to be equivalent to 100 hours at 166 db or 10,000 hours 163 db. During cruise when the structure is at elevated temperature the maximum sound level on any structure is less than 140 db.

11004. STRUCTURAL DESIGN CRITERIA

(1) Fuselage - Fail-Safe

The crack growth history of the second test conducted on the fuselage panel (Ref. D6-18110-4, p. 130) is shown by Fig. 32. Details of this test were reported in the August progress letter, p. 4.

Crack growth testing has been initiated on the third and fourth tests. The third test was started with a series of cracks in the 0.032 gage titanium 6-4 skin at the first row of fasteners at the skin splice. After 2,000 cycles of 12 psi maximum pressure resulted in no noticeable crack extension at this location, the fourth crack growth test was initiated at a center of stringer location in the 0.050 gage titanium 6-4 skin. Testing is continuing simultaneously on the two tests. Test data will be reported upon completion of the tests.

(2) Fatigue Tests

Twenty-three specimens have been fatigue tested to evaluate the effects of the depth of countersunk rivet head penetration. Test results are presented in Fig. 33 and show a general decrease in fatigue life for increased penetration. Eight additional specimens are being exposed at elevated temperature prior to fatigue testing.

Three specimens have been fatigue tested for evaluation of a riveted tapered doubler concept for possible use in fuselage joint design. These specimens were fabricated using current squeeze riveting procedures, and are compared with similar specimens previously fabricated using earlier riveting procedures. The results, presented in Fig. 34, show significantly better fatigue life for the squeeze riveted specimens.

11005. LOADS AND CRITERIA

The speed margin between maximum operating speed, V_{MO}, and design dive speed, V_D, for the B-2707 is based on the requirements of FAR 25.1505. As illustrated in the Mach number versus altitude diagram of Fig. 35, V_D is taken as the greater of; 1.25 V_{MO}, or the speed resulting from a 7-1/2 degree upset from V_{MO} with cruise thrust for 20 seconds followed by power reduction and n = 1.5 pull-up. The maximum design dive Mach number of 2.9 is based on the recommendation of FAA Tentative Airworthiness Standards for Supersonic Transports, FAR 25.1505(b)(2).

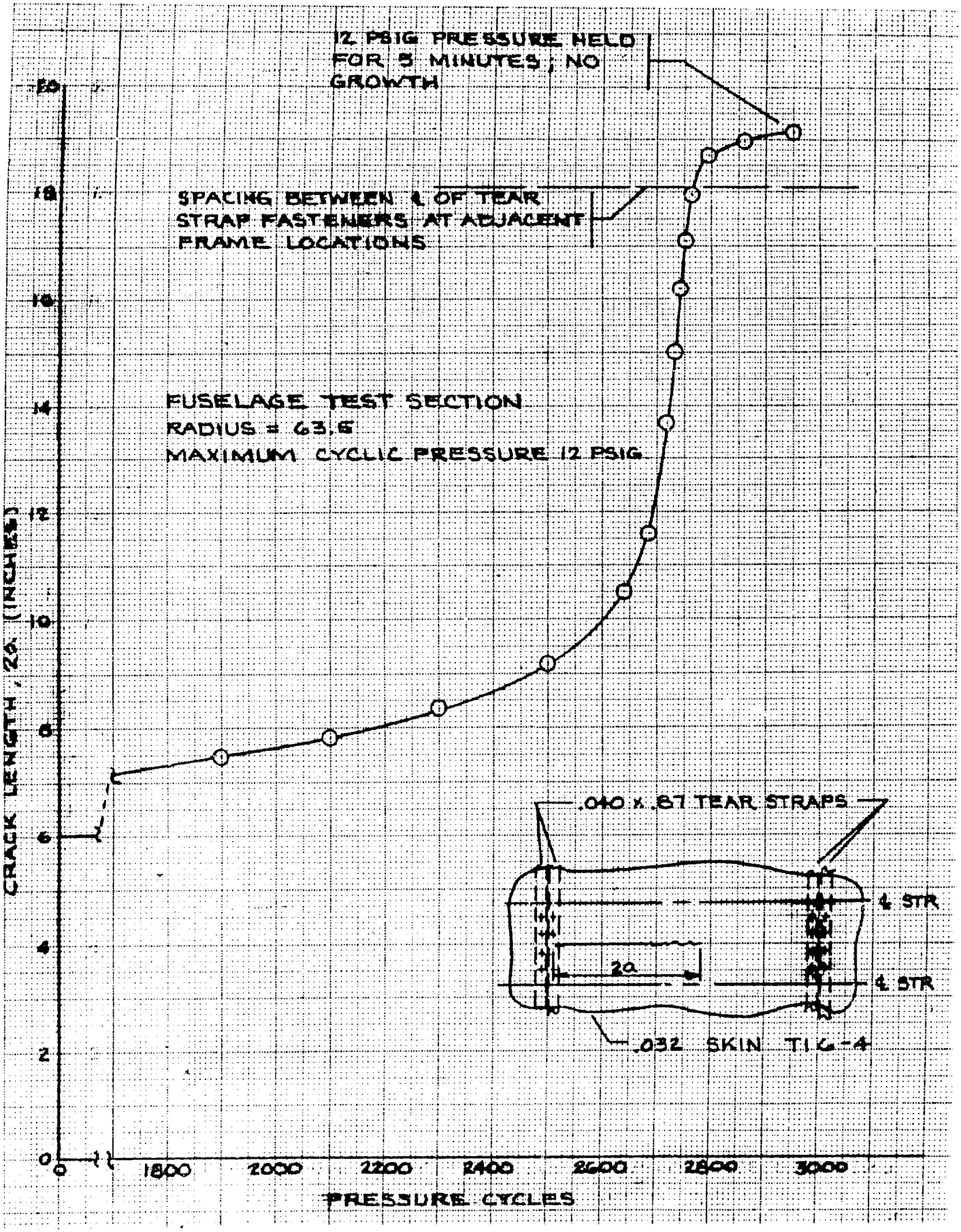


Fig. 32 Fuselage Test Panel No. 4, Test No. 2

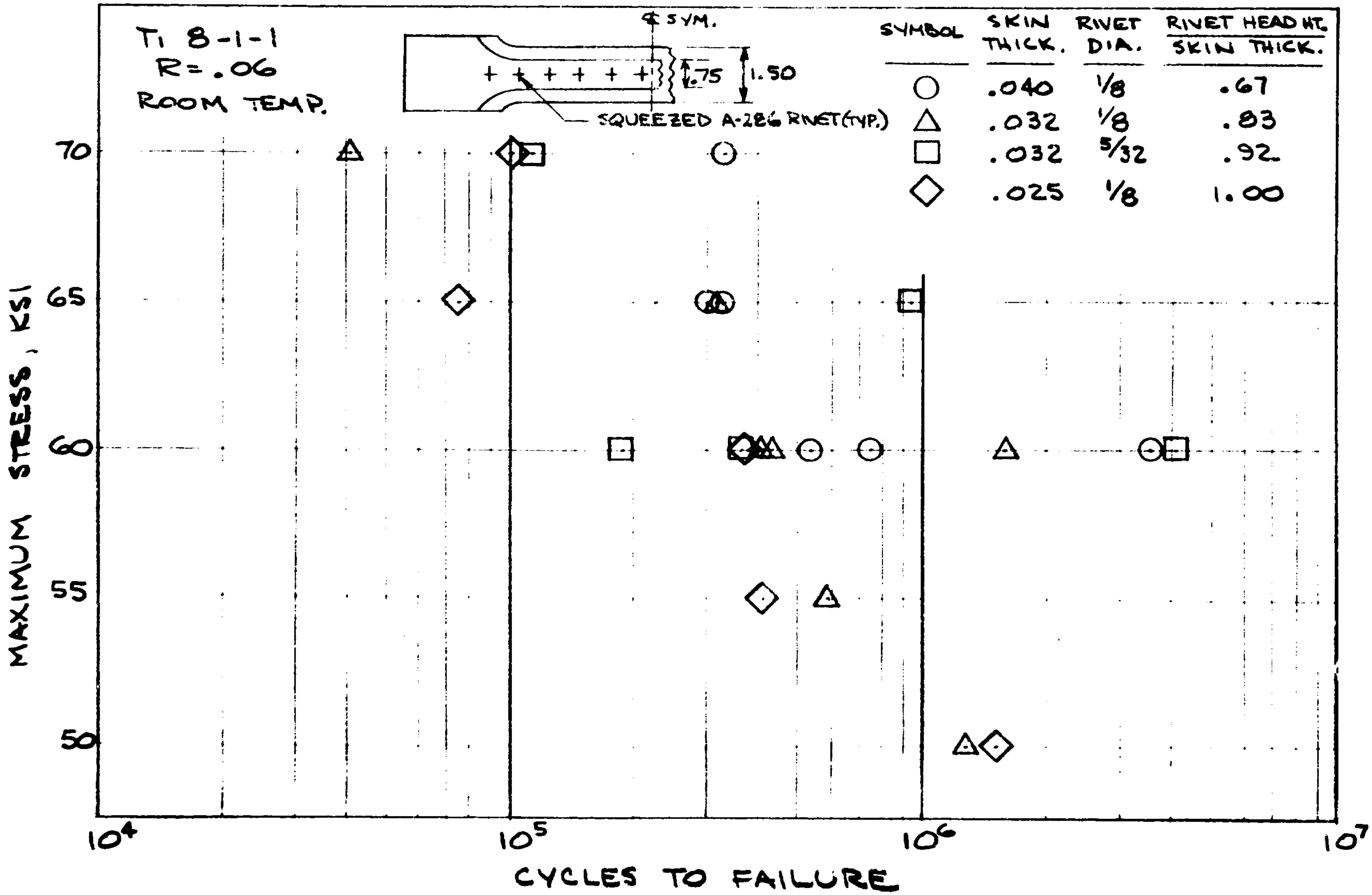


Fig. 33 Effect of Depth of Countersunk Rivet Head Penetration on Fatigue Life

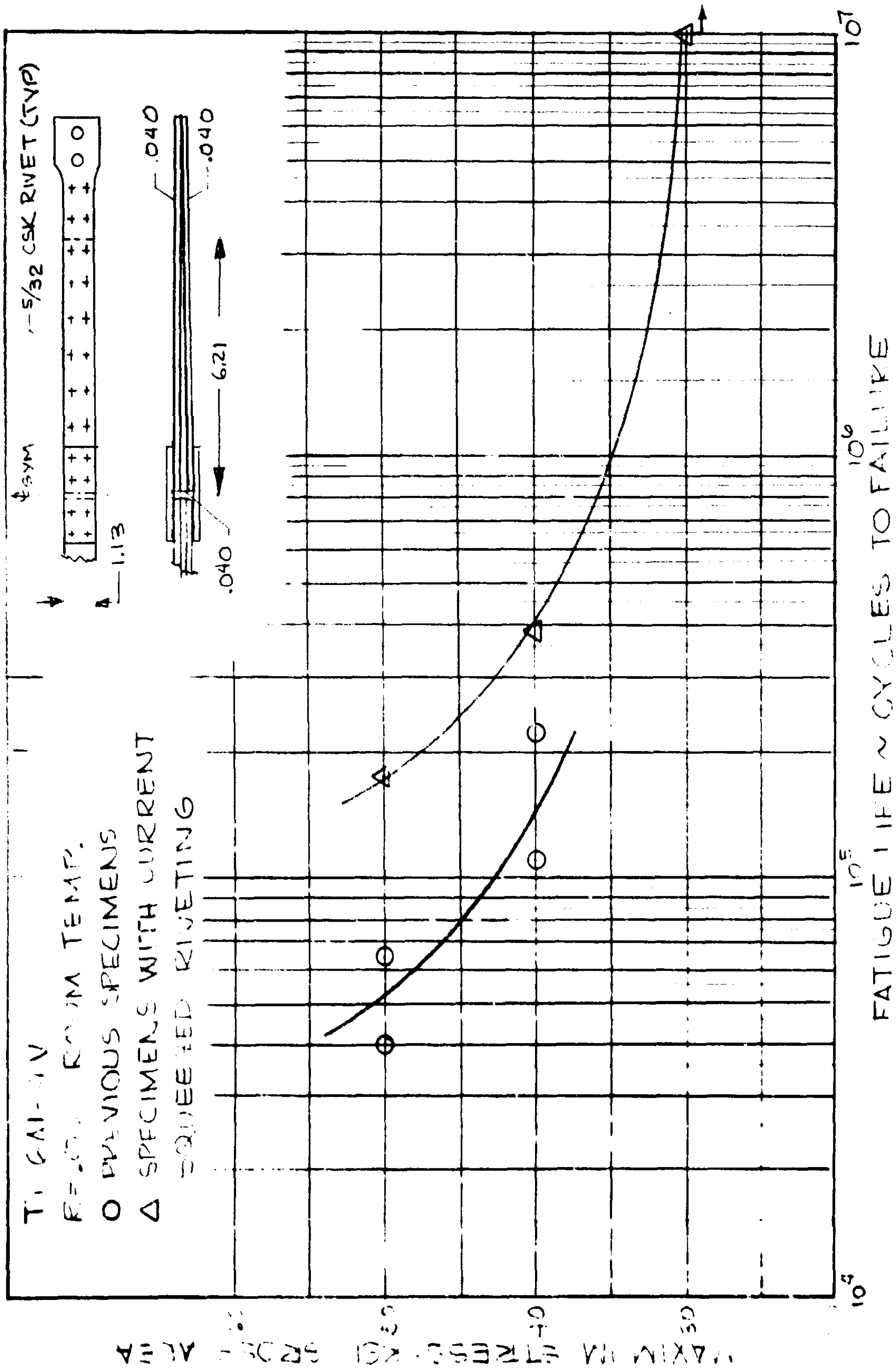


Fig. 34 Fatigue Test Results for Tapered Doubler Specimens

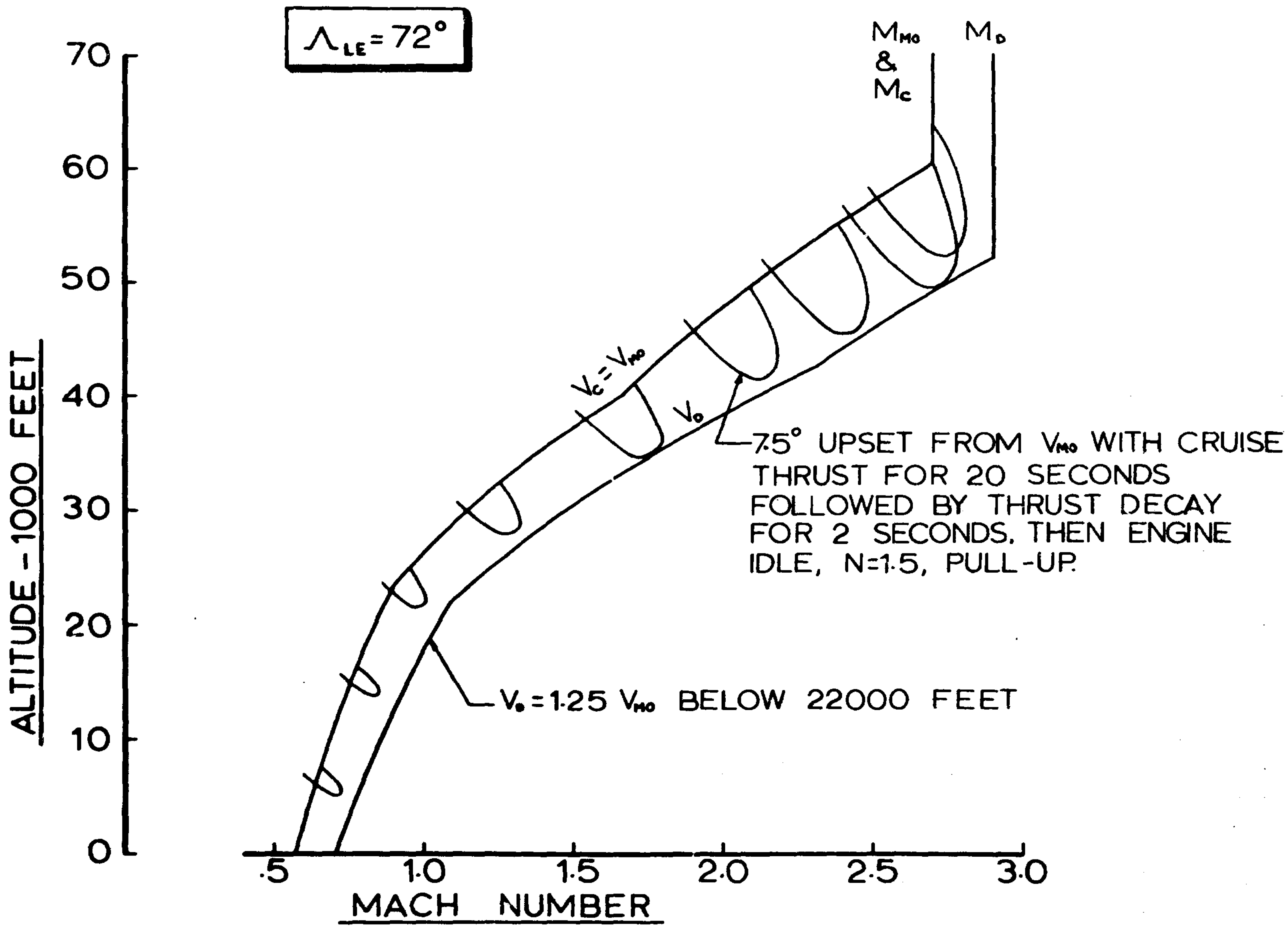


Fig. 35 Design Dive Speed

III. Description of Technical Progress (continued)

11005. Loads and Criteria (continued)

Rational upset and overspeed time history analyses, environmental probability studies, and flight simulator tests have been and are continuing to be conducted to assess the appropriateness of the speed margin. Included in this study are the conditions described in TSS Standard No. 8 for the Concord airplane.

Of some concern in establishing dive speed margins is the acceleration capability of the SST at subsonic speeds. Figures 36 and 37 illustrate the B-2707 overspeeds resulting from level flight acceleration with climb thrust at 7,500 feet.

11006. FLUTTER

The 0.05-scale subsonic flutter model test of the full-span prototype configuration was completed at the Convair, San Diego Wind Tunnel in early August. Summary results of the test were reported in the proposal documentation, V2-B2707-7, submitted Sept. 6, 1966. Detailed analysis of the test data is still in progress.

Testing of a 0.025-scale supersonic flutter model of prototype wing and horizontal tail was completed in the Boeing Supersonic Wind Tunnel on Sept. 20, 1966. The semi-span model installation is shown in Fig. 38. Aerodynamic coupling of the adjacent surfaces is achieved through the test installation. Analysis of test data is in progress.

Testing of the 0.05-scale rigid model of the prototype configuration on the type of cable support to be employed for flutter testing at the Langley Research Center Transonic Dynamics Tunnel was completed in the UWAL Tunnel Sept. 20, 1966. Model stability was checked with wings at 72 degrees and 42 degrees of sweep. Figure 39 shows the model mounted on the cable support in the UWAL Tunnel.

1101. Wing

(a) Tests

The first test has been completed on the wing box failsafe designed lower surface. The lower surface consists of three extruded zee-stiffened panels fabricated from Ti 6-4 condition IV material joined by longitudinal splice stringers. Taper-Lok fasteners are used for skin splicing and attachment of skin and stringers. The center panel is 27.5 in. wide and is stiffened by three "Z" stringers spaced at approximately 6.35 in. A 1.92-in.-starter crack was installed in the center skin panel at a fastener location at the center stringer. The crack was extended by application of a maximum and minimum gross area lower surface skin stress of 30 ksi and -15 ksi. The crack was extended to a length of 10 in. in 12,000 cycles. At this time a 61.5 ksi gross area stress fail-safe load was applied. The fail-safe loading extended the crack tips into fastener holes at the adjacent

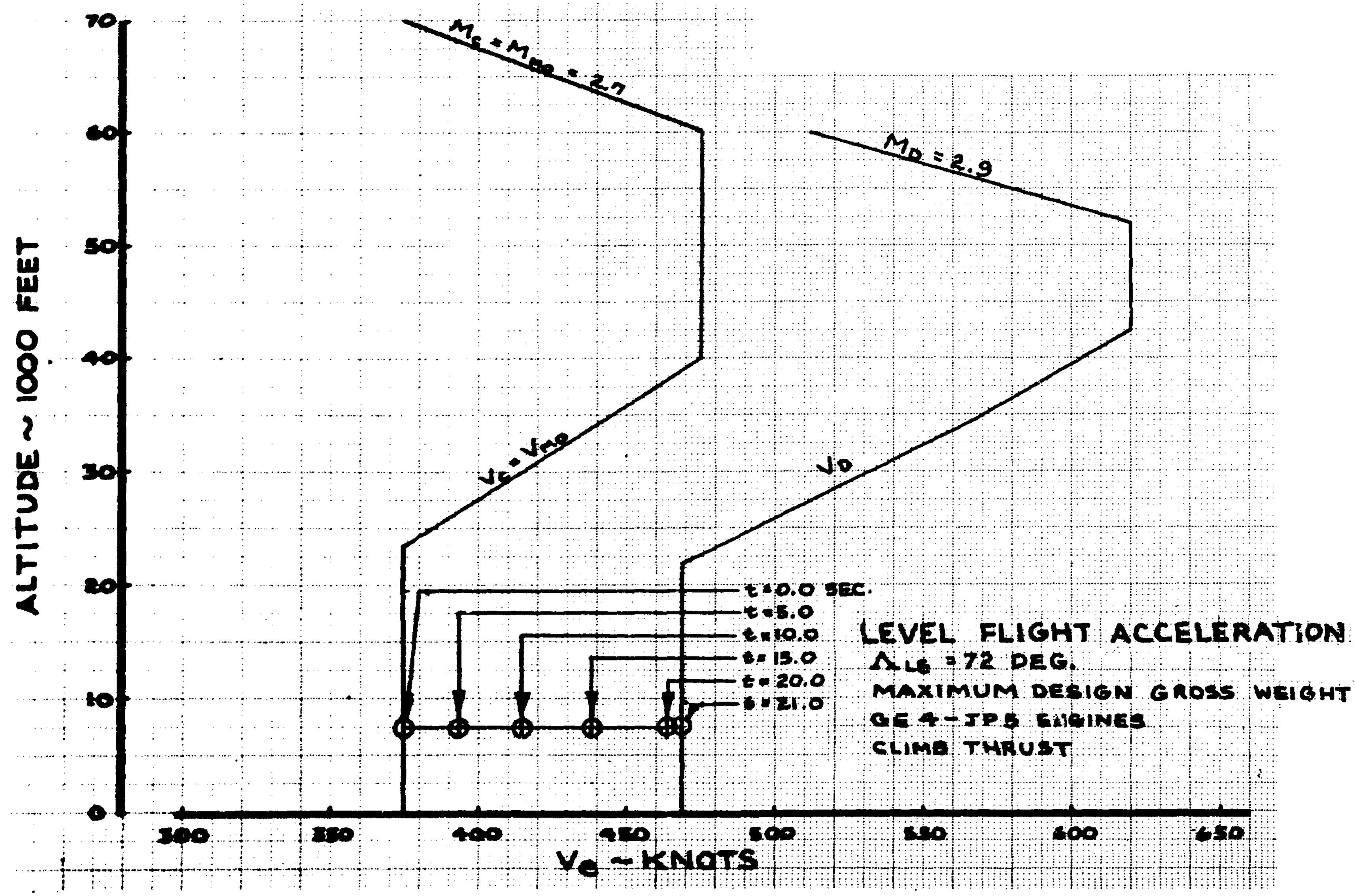


Fig. 36 Subsonic Level Flight Acceleration at $\Lambda_{LE} = 72$ Degrees

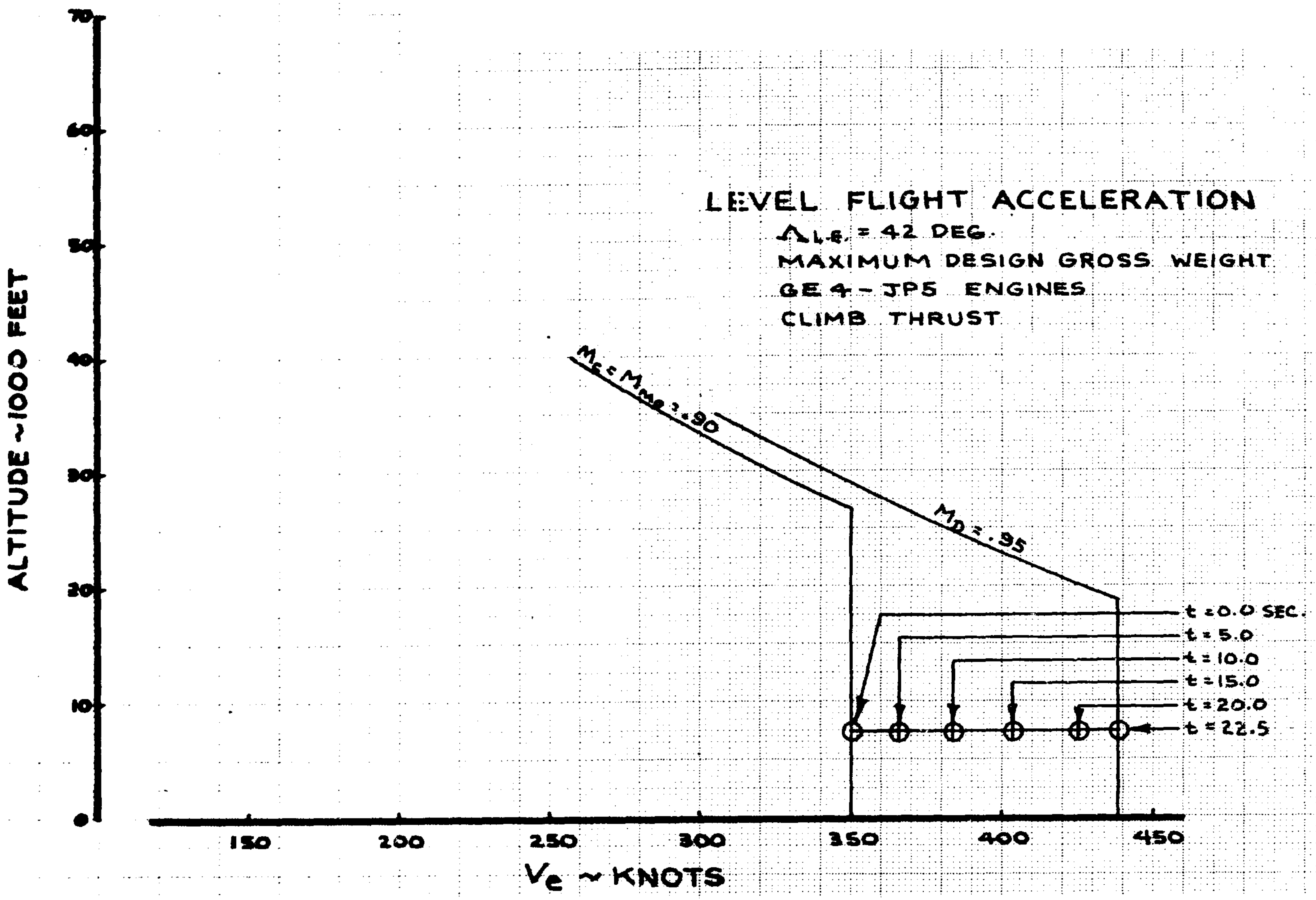


Fig. 37 Subsonic Level Flight Acceleration at Λ_{LE} = 42 Degrees

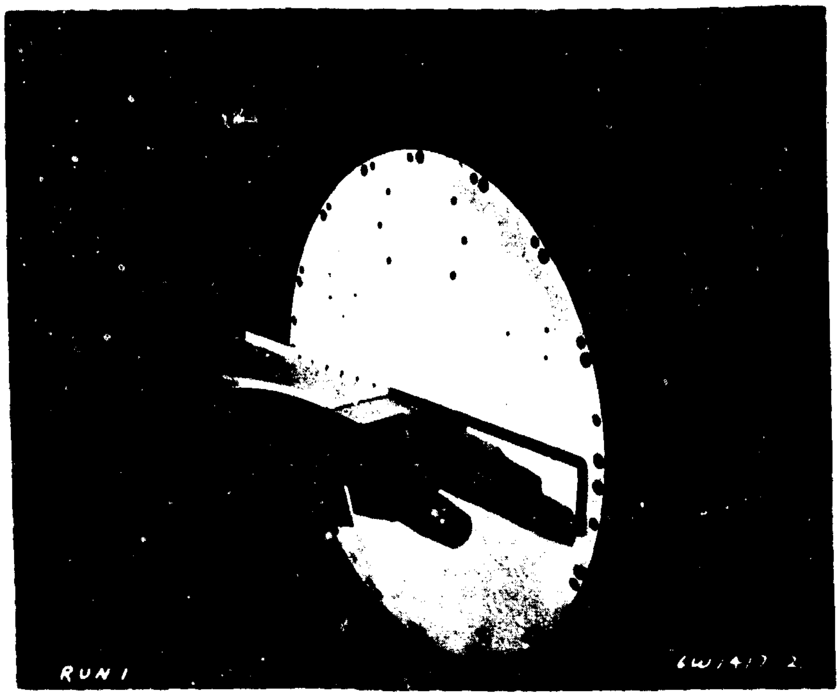


Fig. 38 Boeing Wind Tunnel

Fig. 39 Model in UWAC Wind Tunnel

1101. Wing (continued)

stringers. Normal cycling was resumed, but no additional growth occurred after 500 cycles. At this point a 1-in. sawcut was installed at each end of the existing crack. These sawcuts were centered 1.5 in. from the fastener holes. After 500 cycles, cracks from the 1-in. sawcuts extended into the fastener holes creating a single crack 17.18 in. in length. An additional 500 cycles (13,500 total cycles) extended the crack to a length 20.5 in. at which time another fail-safe load was applied. At 55.5 ksi gross area stress the center stringer failed and loading was discontinued. A fractographic examination indicated that a fatigue crack was present in the stringer at the fastener hole. No other structural damage to the wing box was discovered. The fail-safe loading caused the crack to extend to a length of 24.12 in. One crack tip entered a fastener hole at the skin splice and was arrested. The other crack tip stopped short of a fastener hole at the skin splice. The crack growth history is shown by Fig. 40. The damage was repaired and the second test was initiated by partially severing a "Z" stringer and cycling the box to extend the crack in the stringer. Testing of this configuration is continuing.

(b) Mockups

(1) Leading edge mockup lines will be released on Oct. 1, 1966.

(2) One-fifth scale wing and horizontal stabilizer mockup is on schedule and shall be complete on Oct. 15, 1966.

1104. Fuselage

Completion of assembly tools and start of assembly fabrication of the full size crew compartment has been accomplished. Contracts for the windshields and windows has been awarded to Libbey Owens Ford Glass Company (L.O.F.). L.O.F. will have support from Corning Glass Works for fabrication of chemically strengthened glass. The section including windshields is scheduled for completion by Dec. 31, 1966.

Specification Control documents are in preparation for updating fuselage section work statements to define subcontractor engineering design and testing requirements to assure a coordinated and efficient design effort on an SST Contract Award.

1106. Landing Gear

A significant amount of detail design work has been accomplished on the landing gear. This detail includes: Shock strut, manifold system, truck beam and axles, and up and down locks. Revisions to the landing gear vendor work statements are being made to include the greater depth of detail, allowing a more comprehensive evaluation by the vendors.

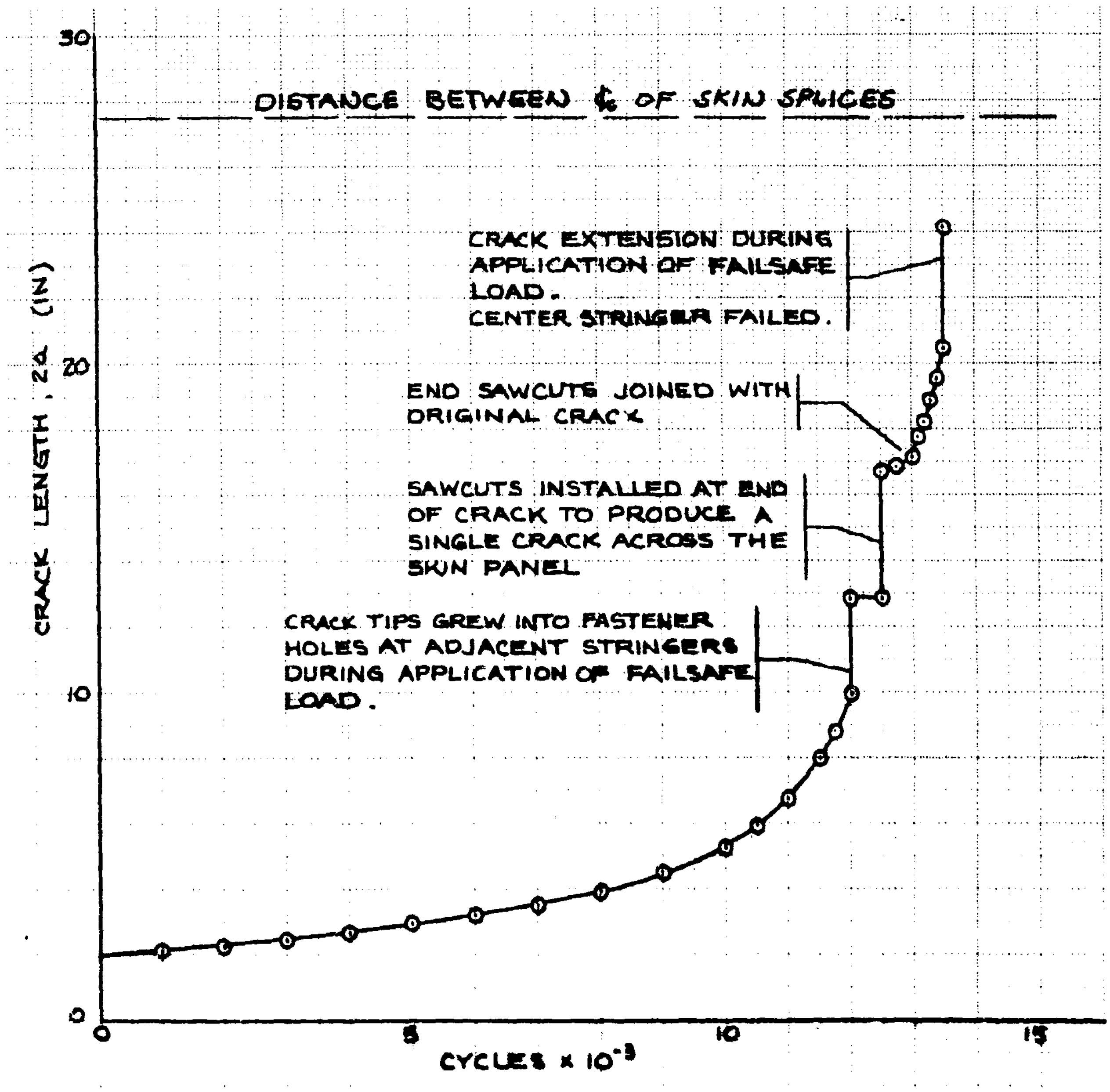


Fig. 40 Wing Box Fail-Safe Panel Test Crack Growth History Test No. 1

III. Description of Technical Progress (continued)

1106. Landing Gear (continued)

Data received from the brake vendors indicates that the brake can be housed in a 19-in.-diameter wheel rim. As a result, the tire size is being changed from a 45 x 19.2 on a 20-in. rim to a 45.5 x 18.7 on a 19-in. rim. The increased 1/2-in. diameter is not critical for the stowage space allowed in the wing and body. The change in tire size results in a change in aspect ratio from 0.65 to 0.71. It is estimated that the improved aspect ratio will increase tire life from 80 landings to 100 landings.

1107. Power Plant Structure

11070. GENERAL

Letter 6-2260-7, "Engineering Evaluation of SST Propulsion Pod Proposal - Aerojet and Rohr," was released on 7-28-66, evaluating each supplier's technical proposal for construction of the SST propulsion pods. The on-site review of Aerojet and Rohr was completed 9-14-66. Final source selection is scheduled for 10-14-66.

The mount systems for the Phase III Proposal were completed 8-15-66. The mount system for the P&WA JTF 17A-21B is shown on P-ENG-601. The layout P-ENG-585 defines the front mount and P-ENG-591 defines the rear mount for the GE4/J5P engine. A stress analysis of these mounts was completed 9-27-66.

1108. Empennage

(a) Design

Design of empennage structures has continued with emphasis on layouts to establish structures designs compatible with systems components. This includes determining space requirements for ducts, control units, auxiliary drive and environmental systems, and integrating these into the structures layouts. Using this information engine support and elevator support structures have been developed as well as other pertinent stabilizer structures.

(b) Testing

Assembly of the composite stabilizer structure is nearing completion and the test fixture is under construction. The leading edge corrugated ribs have been attached to the primary box and those sections instrumented. The 3 honeycomb sandwich panels have been fitted and are being instrumented prior to final assembly. The full depth honeycomb leading edge assembly has completed the bonding cycle and is ready for the cure cycle. Figure 41 shows the empennage primary box and corrugated ribs with the upper panels removed and Fig. 42 shows it with the upper panels in position. The final structure when assembled will be as shown in V2-B2707-9, Airframe Design Report, Structural Tests, Fig. 3-76.

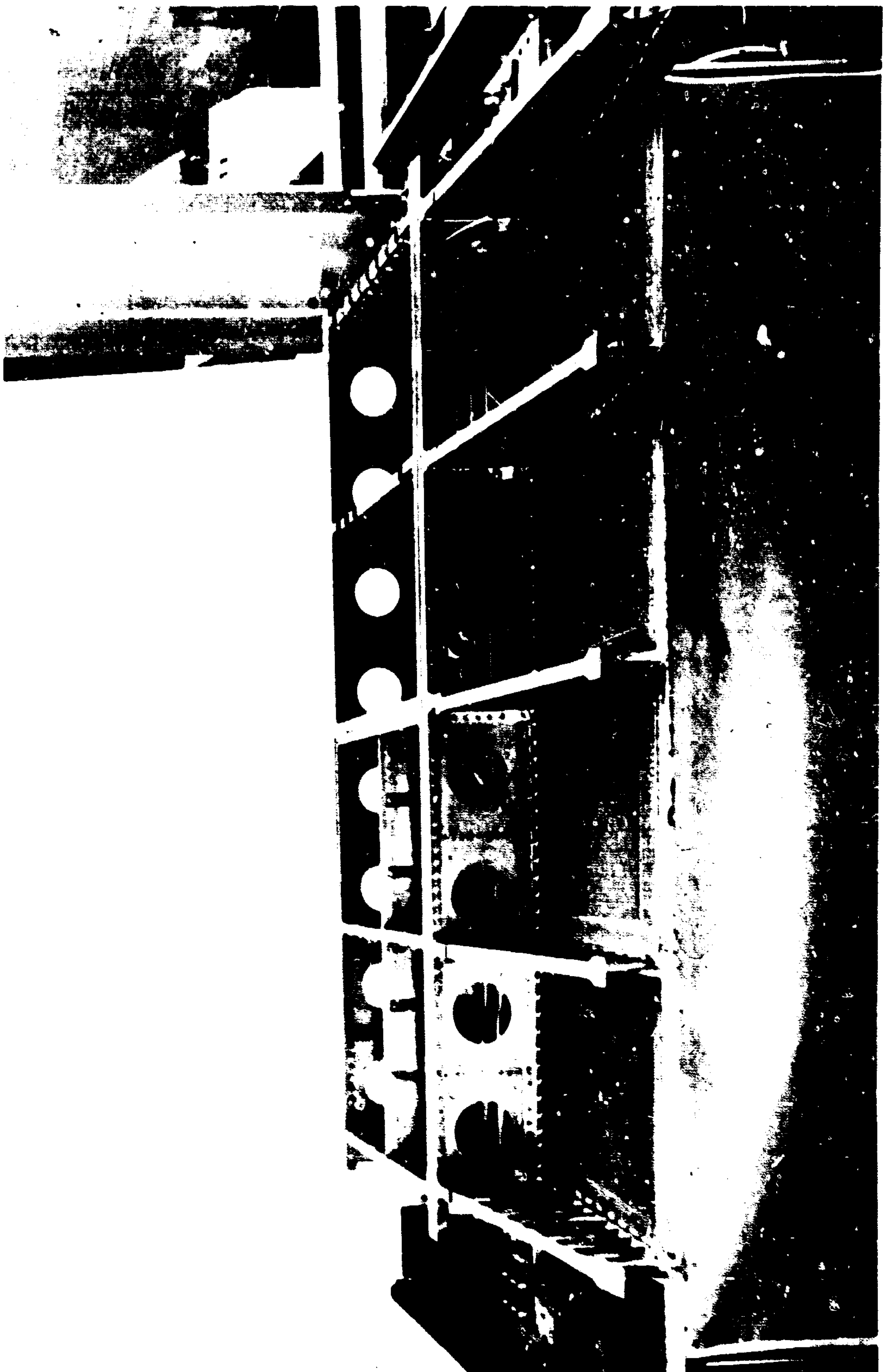


Fig. 41 Empennage Primary Box and Ribs – Upper Panels Removed

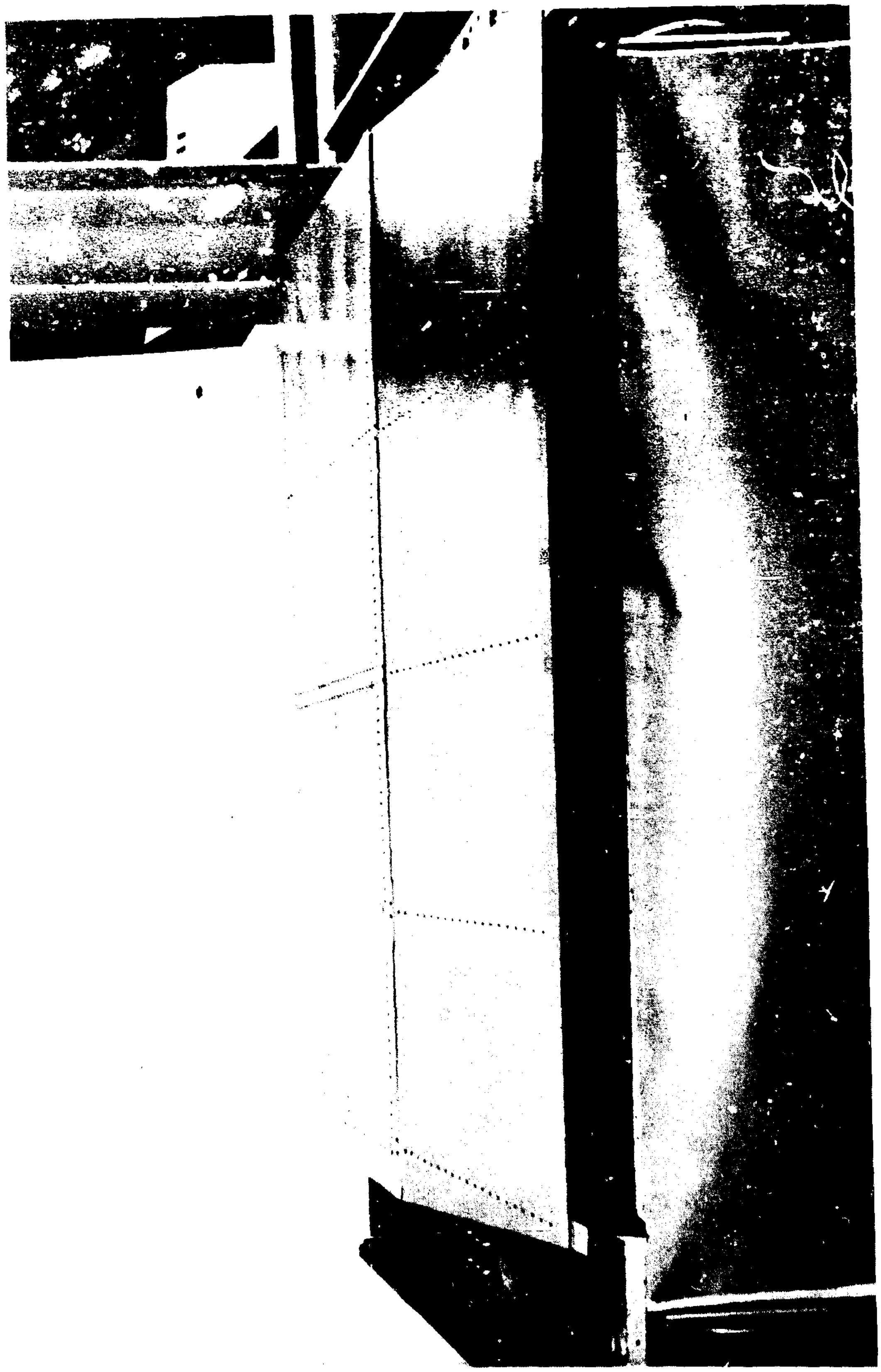


Fig. 42 Empennage Primary Box and Ribs – Upper Panels in Position

D6-18110-7

12. AIRFRAME SYSTEMS

1202. Environmental Control System (ECS)

(1) Compressor Development Program

Assembly of the cabin air compressor test unit was completed and break-in running initiated. During the break-in period, the unit sustained damage to the high speed gear train and gear case. A foreign object entering the gear train is believed to have caused the failure. The unit has been rebuilt and break-in testing is continuing.

The failure has necessitated rescheduling of the 1-day demonstration of compressor performance and operating characteristics from Sept. 15, 1966 (as shown in the Detail Work Plan) to Oct. 7, 1966. Also, the release of updated boost compressor procurement specification has been rescheduled from Sept. 20, 1966 to Oct. 20, 1966.

In accordance with the Detailed Work Plan, the following has been accomplished:

- Environmental control system requirements were finalized and are reported in the Phase III systems proposal document V2-B2707-10.
- The system space locations and basic arrangements were established. The ECS cooling equipment installations were incorporated into a Class I Mockup which included a portion of the left-hand horizontal stabilizer, associated engine pods and the accessory drive system (see Sec. 1206).

(2) System Design

The following system modifications were made and were included in the Phase III systems proposal document V2-B2707-10.

(a) The cabin pressure control system was modified to incorporate control of intrawall exhaust air as a feature of the system. Two electrically actuated cabin pressure control valve assemblies are utilized. Each valve assembly includes a high pressure differential valve located in the intrawall air exhaust duct and a mechanically linked low pressure differential valve mounted on the airplane skin. This modification was made to obtain maximum utilization of cabin exhaust air for cooling and provide increased margin for cabin pressure control when cabin air leakage increases during airline service.

(b) The anti-fogging system for the forebody windows was changed from electrical heating of conductive coatings to a hot air system. This change allows removal of the conductive coatings from the side forebody windows thus improving visibility with the forebody up.

(c) Bleed airflow requirements for engine inlet anti-icing were increased to protect the larger heated areas required by the larger diameter engines. Temperature gages were added to the flight deck instrumentation to provide indication of inlet anti-iced surface temperatures.

III. Description of Technical Progress (continued)

1203. Hydraulic Systems

A design review of the master servo unit was held at Moog's Western development center on August 26, 1966. Moog has incorporated all mutually agreed upon changes and is proceeding with detailing and procurement of vendor supplied items.

Two hundred fifty-five hours have been accumulated on the WSX 6885 fluid in the fluid pump loop test. This fluid has successfully completed the 100-cycle valve stiction test. Examination of the sludge developed during this test is being carried out to determine the cause and corrective action to be taken.

The hydraulic diagrams for all systems have been completed. Design and layout of the landing gear sequence valve installation is in work with one of the valve installations complete.

A study to evaluate a metallic bellows type reservoir has been initiated. A problem statement outlining the requirements for the bellows has been sent to several vendors of this type of equipment.

1204. Flight Control System

In response to our preliminary procurement specifications for the wing-sweep actuator and wing-sweep power control unit, we have received to date, design proposals from three suppliers. We expect to receive proposals from additional suppliers. We are evaluating the industry capability for designing and producing this equipment while familiarizing potential suppliers with our requirements.

System schematics were completed and incorporated into the Phase III Proposal Substantiating Data Document (V2-B2707-11).

Design Support was provided for three significant Class II mockups:

- 1/10-scale model of the wing sweep power control system
- Full-scale wing pivot mockup
- Full-scale airplane mockup

The Flight Controls and Hydraulics Subsystem Specification (D6A10120-1) was updated to incorporate the latest design requirements and also to reflect comments received from the FAA on the Preliminary Release of this document. The updated specification was included in the Phase III Proposal Package.

The developmental servo simulator (DSS) for the Bertea servo-actuator has been modified so that it can provide simulation for several of the types of surfaces to be used on the B-2707. The inertial mass is balanced (semi-flywheel) to allow for simulation of balanced surfaces. However, the addition and subtraction of weights will allow for simulation of unbalanced and trailing edge surfaces.

III. Description of Technical Progress (continued)

1204. Flight Control System (continued)

Through the use of digital computer studies, an aerodynamic loading system has been developed which uses only two loading actuators in push-push. It can be programmed over the full expected range of air loads on the elevon, elevator and rudder at displacements ranging from ± 1.5 degrees to ± 25 degrees. Overtravel to ± 45 degrees is possible at reduced loading rates.

Approximately 10 percent of the drawings of the DSS have been released. A variable rate spring which will simulate structural compliance has been built, calibrated and is ready for installation. Portions of the basic structure are being fabricated. Approximately 85 percent of the purchased equipment for the flight control and hydraulic system has been placed on order. The design of the instrumentation and control system is 50 percent complete. Sixty percent of the instrumentation equipment has been ordered.

The developmental servo simulator will be erected on the reaction slab next to the strongback in Bldg. 9-101-1. Initially, control of the DSS will be from a console located at the fixture. After calibration and trouble-shooting have been completed, control will be from either a pilot's console on the floor or the instrumentation room in 9-101-2.

The stability augmentation system triple actuator which is part of the 10-61061 servoactuator being built by Bertea was sent to Boeing for test and evaluation. Laboratory studies showed the need for small modifications to the basic design. However, the triple package was deemed suitable for further use. It was, therefore, returned to Bertea for inclusion in the 10-61061 assembly.

1205. Electrical Systems

12052. ELECTRICAL POWER SYSTEM

Refinements in the design of the Electrical Power System have resulted in the addition of windmilling power capability to the VSCF generators. This feature permits the use of windmilling power for engine ignition purposes and reduces the size of the standby battery source required to meet the 4 engine out requirement. Windmilling power is available from the VSCF generator between the limits of 10 and 95 percent of engine idle speeds in the form of 28V regulated direct current.

The capacity of standby power system for the unlikely event of four engines out condition has been investigated and it was determined that a 26 amp hour 28V DC storage device is adequate.

12052. Electrical Power System (continued)

An automatic load reduction scheme was proposed to guard against overloading the electrical power system in the event of single or multiple generator failures. Non-essential loads such as water heaters and galleys will be automatically switched off when one or more of the generators are removed from the parallel system and load on the remaining system exceeds 100 percent per channel.

Further refinements were made in the packaging and installation of electrical power system components and an equipment list was generated for the system configuration. The majority of the electrical power system equipment will be installed in the aft equipment center at station 3020.

Electrical Power Generation - Aids Interface

The interface between the electrical system and AIDS has been established. The AIDS will be used to supplement the information available from the electrical system's annunciators. AIDS will be supplied data from only one generating channel through which it will identify whether the failed component was the generator, generator oil cooling loop, frequency converter or feeders. Also AIDS will monitor a transformer-rectifier unit and the standby power panel.

Advanced Flight Engineer's Monitor Station

An advanced concept (pushbutton) control panel for the electrical power system has been designed and fabricated. The control panel was developed around the use of existing hardware. The control panel has been integrated into a fully functional display which was available during the on-site FAA review.

12053. AIRPLANE LOAD ANALYSIS

Revision B to the "Electrical Load Analysis - B-2707" was released, with the modifications required to support the Phase IIC proposal. This load analysis validates the selection of the electrical power generation and distribution systems and proves the practicality of "isolated" and "split-parallel" power distribution.

Remote Circuit Breaker

The existing remote circuit breaker procurement specification (10-61115) defines the requirements for electromechanical and solid state breakers having three separate circuits from each control and indicating device to the remote breaker. One wire is required for resetting the breaker, one for tripping, and one for status indication with the airframe used as a common ground return. In an attempt to reduce airplane wiring weight and congestion, a method of control has now been originated which will allow all three functions to be accomplished by a single wire and airframe return. Although this method has not been proven, it utilizes known principals which are within the

III. Description of Technical Progress (continued)

12053. Airplane Load Analysis (continued)

present state-of-the-art for circuit breakers and appear to be completely practical for airplane use.

A patent disclosure has been initiated on the application principals and further investigation is in progress. It is planned that definition of the new control method will be incorporated into the remote circuit breaker specification revision to be released early in the Phase III contract period.

External Lighting

D6A10064-6, "Electrical and Lighting - SST Reliability Analysis," was released on Sept. 14, 1966. This document gives a reliability analysis of the electrical power generation subsystem, lighting subsystem (both external and internal lighting), and the windshield heating subsystem. The conclusions reached were that the subsystems investigated will meet the FAA and Boeing inflight reliability goals.

D6A10373-1, "Multichannel Control and Indicating Subsystem for the Model B-2707 Supersonic Transport," was released on Aug. 11, 1966. This document details a multiplexing system constructed mostly of integrated circuits. Built-in transient protection circuitry has been incorporated. The multiplexer, when used with an advanced packaging technique, appears to have weight and cost advantages over point-to-point wiring.

Anti-Collision Lights

The Anti-Collision Lights section of document D6A10019, SST Lighting Systems, was revised to be compatible with the B-2707 configuration. Refinements were made to the collision avoidance study to determine the minimum factors required of an anti-collision light system for effective use during supersonic conditions. The minimum anti-collision light sighting distance for head-on collision avoidance with 1,000 ft. vertical clearance was determined to be 21.00 miles. The required light intensity will be 1,650 candles at that distance. As a result, it is recommended that anti-collision lights be used only during subsonic flight. A request has been made through the Aerospace Industries Association (AIA) that a subparagraph be added to FAR 25.1401 stating: "The Anti-collision light system need not be operative during supersonic flight".

The following documents related to the B-2707 configuration were also released:

D6A10257-1	Lighting Protection for Supersonic Transports
D6A10262-1	Rev. A Antenna Radiation Patterns for the SST
D6A10388-1	SST RF Coaxial Cables & Connectors
D6A10393-1	HF Antenna Configuration Study for the SST

12056. WIRING AND TERMINATIONS

Engine wire harnesses with metal jacketed cables, interface box and flexible conduits, have been installed on both engine mockups. This was done to illustrate the concept for engine wiring disconnect, and to check clearances with the cowling and other engine components.

Alternate methods of routing the electrical wiring across the wing pivot area have been investigated. As a result, a design concept of routing the wire harnesses through the pivot area adjacent to the other systems seems to be the most favorable.

A wing pivot wire bundle flexure test fixture and heating oven have been completed. Three flexible conduit design concepts with wire bundles have been installed on the fixture for a motion study. It is planned to obtain high temperature conduits and start testing the most promising concepts during Phase IIC.

One concept utilizing a teflon grommet which allows teflon covered flexible conduits to slide through it, was fabricated and installed on the full scale wing pivot mockup. The cable assembly ends are terminated in junction boxes to illustrate areas that could be used for circuit check out or cable replacement.

<u>Zone A Connectors</u>

The connectors for use in Zone A (pressurized areas) are exposed to conditions nearly the same as subsonic airlines. The following selected connectors use existing technology:

(a) Circular connectors are based on MIL-C-26500 technology with modifications to strengthen small contacts and to improve maintainability.

(b) Rectangular connectors of a new design will use contacts common with the circular connector and the same design approach. The rectangular shape provides double the contact density for limited space applications.

(c) Rack and Panel connectors are specified in the ARINC standards. These are Cannon DPX's and DPA's.

<u>Zone B Connectors</u>

The maximum temperatures in Zone B (unpressurized areas except engines) are at the upper limit for silicone elastomers suitable for connectors. Recent tests at Wichita have confirmed that the silicone rubbers and adhesives have short life (less than a few hundred hours) above 400°F. The major connector companies have offered no other elastomer for sealing the wires and shells. The design solutions offered for the SST are:

III. Description of Technical Progress (continued)

12056. Wiring and Terminations (continued)

(a) Accept limited connector life for Zone B on the prototype aircraft.

(b) Develop a teflon dielectric connector which uses the same insulation as the wire (550°F maximum). This development involves adding thermal compensation to an existing liquid rocket engine connector.

(c) Develop improved silicone elastomers or other materials.

Zone A and B General Wire

The electrical wiring has three critical requirements:

(a) Chemical resistance to various liquids

(b) Long life equivalent to 50,000 airframe hours, and

(c) Suitability for -65°F to +450°F temperatures.

The best available wire insulation which satisfies these and other requirements is TFE teflon. The selected wire conforms to MS18001 in which the teflon has a mineral filling and the copper conductor has a nickel-clad jacket.

Aluminum Feeders

Aluminum electrical conductors weigh one-half as much as copper conductors of the same resistance. However, the aluminum has a larger cross-section area requiring a corresponding larger amount of insulation which balances out part of the weight savings.

The evaluation of aluminum conductors considered applications as the four forward feeders and the ground power feeder (Trade Study 33-4-132). Aluminum wire showed a potential weight savings of 300 lbs. per airplane, but with the drawbacks of needing careful control of crimps and terminal stud connections. However, suitable techniques to handle the aluminum terminations have extensive service applications in B-52 G&H aircraft.

Another drawback is that aluminum will not withstand the temperatures needed to sinter teflon, so the wire must have a different insulation. This wire is presently being developed for Boeing subsonic airliners.

Therefore, aluminum feeders appears desirable and feasible for use on the B-2707.

Electronics Rack Mockup

Detail drawings were released and fabrication was completed on the Class I forward electronics rack development mockups. This mockup contains system black boxes, connectors and wiring to demonstrate

12056. Wiring and Terminations (continued)

equipment installation methods and wiring techniques. In addition, an electronics interface unit was fabricated to show access to system interconnections and demonstrate modification methods.

1206. Accessory Drive System (ADS)

(1) The following items were accomplished in accordance with the detailed work plan:

(a) The accessory drive and air turbine starter requirements were fixed and submitted in the proposal document V2-B2707-11.

(b) The space location and basic arrangement for the ADS were fixed and are shown in the Class I mockup.

(c) The Class I mockup installation was completed.

(d) The gearbox heat loads and oil cooling configuration were fixed and submitted in the proposal document V2-B2707-11.

(2) A transient thermal analysis was made on the ADS cooling system and it shows that the system is adequate. Oil temperature during normal operation is 261 degrees maximum. During rapid descent after loss of cabin exhaust air cooling, the ADS peak oil temperature is 335°F. The analysis summary is presented in V2-B2707-11.

(3) Sundstrand ADS Development Program

(a) A coordination meeting was held at Sundstrand on Sept. 1-2, 1966.

(b) Sundstrand has successfully conducted preliminary tests on each of the gearbox pads to maximum design load. The Demonstration Test will be held on September 30 and October 3 at Sundstrand as originally scheduled.

(4) Hamilton Standard ADS Development Program

(a) A coordination meeting was held at Hamilton Standard on Aug. 30, 1966. A review was conducted of the in-house and vendor supplied components which are behind schedule. The completed ADS components and test equipment were inspected.

(b) Due to the late delivery of some of the ADS components, the date for the Demonstration Test has been changed from Oct. 10 to Oct. 17, 1966.

(c) The 1000-hour oil compatibility and gear lubrication tests were completed during the reporting period and the test results were favorable.

III. Description of Technical Progress (continued)

1207. Automatic Flight Controls

The AFCS portion of the Phase III proposal was prepared and included in V2-2707-11, forwarded to the FAA September 6. The subsystem specification (D610120-1) was updated and released. Questions on the proposal documentation were received from the FAA and answers presented in the on-site evaluation held during the week of September 19.

Included in the back-up data presented during the on-site review were formally released copies of the following documents and drawings.

(1) D6A10385-1, A/P Modes Operation and Description

(2) D6A10339-1, FCE Development Data Document

(3) 65A10140, AFC System Drawing, sheets 1-8

(4) D6A10064-4, Reliability Analysis Document

The updated autopilot and SAS design (Detail Work Plan item 2100) is included in the 65A10140 drawings.

A preliminary determination of the SAS Authority Requirements (Detail Work Plan item 2170) has been defined and will be included in the next revision of the subsystem specification (D6A10120-1).

Proposals were received from prospective AFCS suppliers and reviewed. A Statement of Work is being prepared and will be forwarded to prospective AFCS suppliers. The selection of the AFCS supplier (Detail Work Plan item 5063, 5263) has been postponed until early in Phase III.

1208. Flight Deck Installations and Systems

The Class II flight deck mockup was updated to reflect airlines' specialists committee recommendations. This updating, together with the installation of powered crew seats, was completed prior to the on-site evaluation team review.

12081 INSTRUMENT AND CONTROLS ARRANGEMENTS AND DISPLAYS

It has been decided to fit the B-2707 with a television camera to augment the pilots' vision during ground maneuvering and landing approach. The camera is mounted in the ventral fin and will provide a view of the extended main and nose landing gears through a zoom lens which will be controlled from the pilot stations. The picture will be displayed on a time shared basis with either the weather radar or the attitude indicator, depending on the results of Phase III development

12081 Instrument and Controls Arrangements and Displays (continued)

programs to establish the best approach. These programs will be conducted to evaluate the suitability of scan conversion techniques for displaying weather radar on a raster scan tube to permit time sharing the CRT normally reserved for weather radar information. They will also evaluate the potential of TV tube displays for the attitude director indicator (ADI) functions, and for combined ADI and TV monitor applications.

An advanced panel configuration based on these concepts, and containing a moving map display, was exhibited and discussed during the on-site meetings.

12083 RAIN REMOVAL SYSTEM

The primary in-flight rain removal system employs rain repellent fluid and depends on the aerodynamic air flow to remove the rain droplets from the windshields. The auxiliary, or ground taxi, rain removal system has been changed from the air jet blast system of earlier Boeing SST proposals to windshield wipers. This change was made following the completion of a rain removal system trade study, D6A10187-1, which compared wipers plus repellent with air blast plus repellent systems. The trade study showed that the wipers will have better rain removal performance in mist and excessive rain conditions than the air blast systems. They also are a lower cost and lower weight installation (1 to 3 pounds). In addition, the wipers can be used for washing the windshield, whereas the air blast systems cannot. No technical difficulties are expected in developing acceptable wipers, since suitable heat resistant materials are now available.

Documents D6A10136-1, Flight Deck Instrumentation and Controls for the B-2707 Ice and Fog Protection Systems, and D6A10137-1, B-2707 Rain Removal System, have been published.

12085 AIRPLANE SURVIVABILITY/ESCAPE SYSTEM STUDY

Document D6A-10167-1, Summary Report - Preliminary Aircraft Survivability/Crew Escape System Study, was published and discussed with the FAA during the on-site evaluation. The point was made by the FAA that FAR 21.350 must be waived or ammended to make the proposed in-flight egress provisions acceptable.

1209. Communications

Document D6A10393-1 entitled, "HF Antenna Configuration Study for the SST Airplane," was released. The document includes impedance and radiation pattern data for the proposed HF antenna system.

III. Description of Technical Progress Report (continued)

1209 Communications (continued)

Procurement Specification 10-60985, Audio Control Center, was released.

Supplier proposals for the 10-61003, Remote Frequency Selector, have been received.

1210. Navigation

Procurement specifications 10-61079, Pitot-Static Pressure Sensor, and 60A10035, Airflow Direction Sensor, have been released.

Supplier proposals for 10-60972, Weather and Ground Mapping Radar, 10-60977, Integrated Flight Instruments, 10-60973, ADF Loop Antenna, 10-60974, Radio Altimeter Antenna, 10-61086, L Band Antenna, and 10-61088, Marker Beacon Antenna, have been evaluated.

The following reports were completed:

(1) Memorandum 6-7716-30-029 entitled, "SST -2707 Glide Slope Antenna System." The report describes antenna types considered for the SST Glide Slope System.

(2) Memorandum 6-7716-30-025 entitled, "SST -2707 Tail Cone VOR Antenna." The report describes the proposed VOR antenna patterns.

(3) Memorandum 6-7716-30-028, entitled, "SST -2707/Localizer/VOR Antenna System." The report describes the antenna types considered for the SST VOR/LOC system.

1211. Electronics General

Document D6A10122-1 entitled, "Navigation Communication Subsystem Specification," was released. The document describes the function and requirements of each system in the subsystem.

Document D6A10064-3 entitled, "Aircraft Integrated Data System Reliability Analysis," was released. The document serves as a record of reliability analyses and data used in the design development of AIDS.

Document D6A10236-1 entitled, "Electrical Bonding and Grounding Requirements," was released. The document describes the bonding and grounding plan for the SST.

Document D6A10090-1, entitled, "Aircraft Integrated Data System Subsystem Specification," was released. The document describes the function and requirements of the system.

III. Description of Technical Progress (continued)

1211 Electronics General (continued)

Document D6A10388-1 entitled, "SST RF Coaxial Cables and Connectors," was released. The document describes cable test results and cable and connector types recommended for the SST.

Document D6A10262-1, entitled, "Antenna Radiation Patterns for the B-2707 SST," was released. The document includes radiation patterns for the navigation and communication antennas proposed for the SST.

Supplier proposals for 10-60976, AIDS, have been evaluated.

A report - Lightning Protection for Supersonic Transports, D6A10257-1, has been completed. The purpose of the report is to provide a general guideline in developing and employing lightning protection techniques for supersonic transports. The document describes the various characteristics of natural lightning and their associations with flight safety and maintenance. Design criteria are discussed as well as methods used to verify final design of lightning protection configurations.

Radomes

Determination of dielectric properties of various polymide laminates after long time exposure to a 500°F environment has been initiated. Data up to 1250 hours is presently available.

Revision A of the Materials Selection Document, BR-862-122-001 and Wyle Laboratories Report 40742-1, "Environmental Testing of Filament Wound Panels for the SST Radome," were received from the Brunswick Corporation. The first full-scale polymide radome has been electrically tested and is presently being subjected to structural tests.

1212. Fire Detection and Protection

Document D6A10064-14, "Reliability Analysis Document - Engine Installation and Fire Detection/Extinguishing," was released 9-6-66 containing a failure mode and effect analysis of the fire detection/extinguishing system.

12122 FIRE DETECTION SYSTEM

Coordination sheet SSP-ENG-1290 was released to the Mechanical Equipment Staff Unit to begin the fire detector response time tests.

1213. Passenger and Cargo Provisions

12130 PASSENGER AND CARGO ACCOMMODATIONS, GENERAL

The Passenger and Cargo System input to the "systems" portion of the B-2707 proposal documentation was completed.

Backup files were completed for the Federal Aviation Agency's on-site review. The files consist primarily of documents, drawings, reports and data referenced in the B-2707 Proposal Documentation.

Documents updated and released were:

(1) D6-2556 Seat Design Criteria

(2) D6-6956 External Decorative Marking Specification

(3) D6-6908 Interior Colors and Materials

(4) D6-6954 Galley Design and Installation Specification

The Passenger and Cargo System was evaluated for one week in conjunction with an on-site review team of the Federal Aviation Agency.

All questions asked by the Federal Aviation Agency's on-site review team were categorized, tabulated, answered and reviewed during the period of their stay.

A 30-foot sectionalized full sized mockup representing cross sections of the B-2707 body was completed. The purpose of the mockup is to demonstrate comparisons of the five, six and seven abreast seating and associated spacing. The seven abreast seating arrangement is an optional design with widened fuselage at the wing apex station, described in proposal document V2-B-2707-1, Section 7.0, of the System Engineering Report.

Preparation of a Fire Safety Demonstration Plan has been initiated. This plan is due for release by December 1, 1966. Coordination has been established with the CAD in connection with their plans for full scale 727 fire safety tests expected to be accomplished within a year.

12132 EMERGENCY EQUIPMENT

A meeting was held with Passenger and Cargo Accommodations engineers representing other projects of the Commercial Airplane Division. The purpose of the meeting was to consider the possibility of developing a common Boeing Specification for Emergency Escape Slides.

III. Description of Technical Progress (continued)

12132 Emergency Equipment (continued)

Points of Commonality discussed included:

Environmental Testing
Color of Slide Container
Reliability Requirements
Placarding
Release Handle Pull Force Requirements
Pull Handle Color Requirements
Slide Illumination Requirements
Tear Resistance
Flame Resistance
Static Electricity Requirements
Leak Rates
Life Cycle Tests

It was concluded that in the interests of economy and simplicity, universal escape slide requirements are desirable, although no definite conclusions were reached regarding details.

After further study by each project additional meetings will be held, not only to consider further the areas of commonality, but to reach agreement on specification presentation for those areas.

12136 CARGO PROVISIONS

A full-scale demonstration of a side loading cargo containerized system was completed. The mockup is approximately 35 feet in length typifying the forward cargo compartment. Six containers were built to demonstrate containerized loading and unloading.

The mockup was also used to evaluate configuration and installation, safety, reliability, interfaces, and other design parameters.

Work on the resolution of the following cargo loading problems was initiated:

- New Hoist Drum Concept
- New Hoist Chain System
- Traverse System Containers

III. Description of Technical Progress (continued)

13. PROPULSION SYSTEMS

1300. Propulsion System – General

Document D6A10064-14 "Reliability Analysis Document - Engine Installation and Fire Detection/Extinguishing", was released 9-6-66 containing a failure mode and effect analysis of the engine installation.

13002 POD MOCKUP

Layouts have been released and mockups have been completed of the P&WA and the G.E. engine configurations. These mockups were completed 8-31-66 and were available for the FAA on-site evaluation held from 9-19-66 through 9-24-66.

1301. Performance (Installed)

In response to specific airline requests for supplementary B-2707 data, additional GE 4/J5P and JTF 17A-21B engine performance data was prepared for use in B-2707 performance and airport noise evaluation.

1302. Air Induction System

(1) Inlet Test and Analysis

(a) Inlet Flow Field Tests

An inlet flow field survey was made on a B-2707 airplane model which is of the same configuration as that sent to NASA largely for evaluation. Figure 43 shows two photos of the model including the interference fences, landing gear fairings and wing pivot fairings. During the test both the General Electric and Pratt and Whitney propulsion pod locations were examined.

The new flow field data was found to be similar to that presented in the proposal for earlier testing. The inlet local Mach number during a cruise at a body angle of attack of 6 degrees was found to be 2.7 for the GE inlet positions and 2.75 for the P&W inlet positions. The variation of inlet local Mach number with angle attack is shown in Fig. 44. Contours of constant Mach number for the 2 engine locations are shown in Fig. 45.

The variations of the inlet local incidence angle with angle of attack are shown in Fig. 46. The airplane can maneuver through the angle of attack range with only a 2-degree inlet local angle of incidence change.

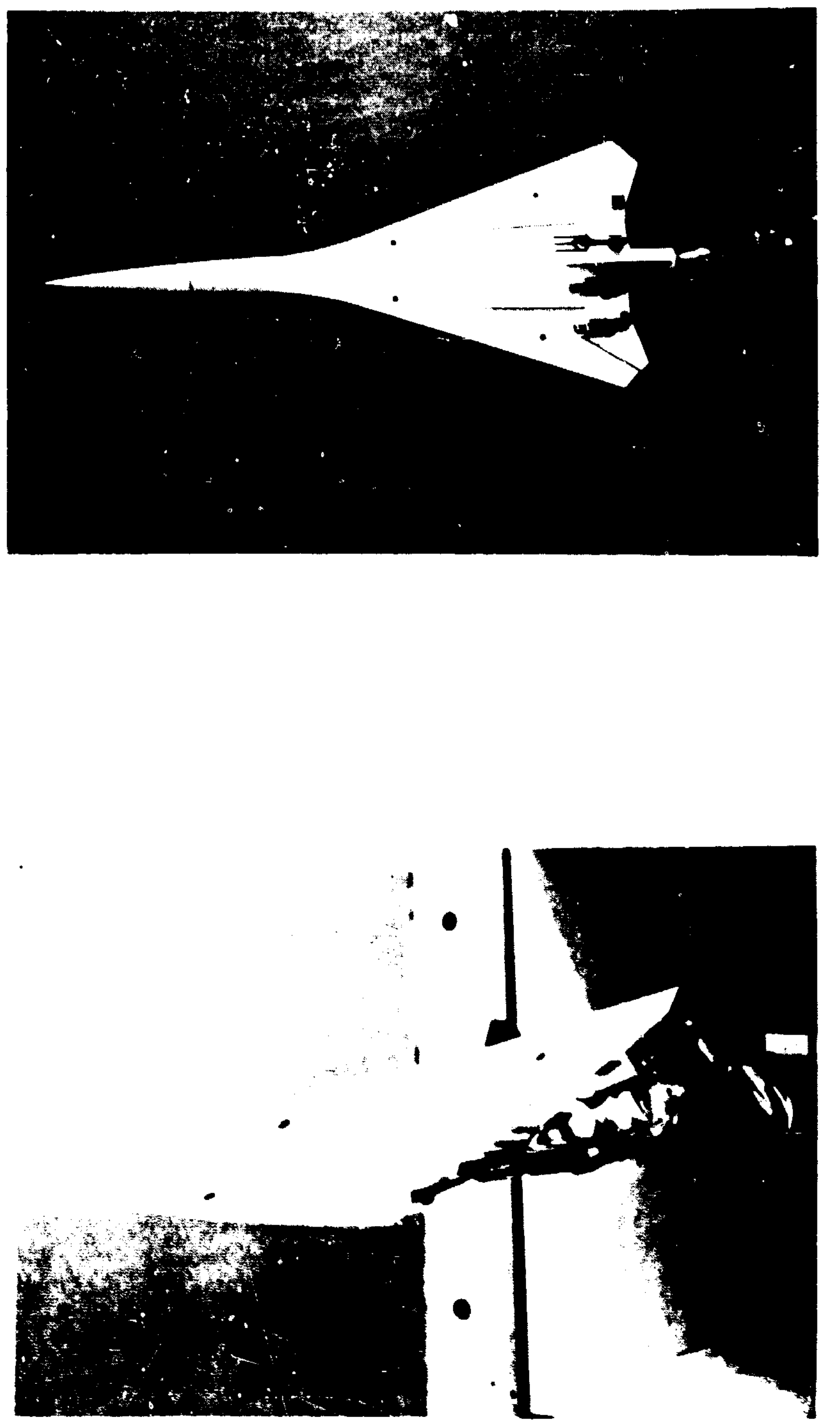


Fig. 43 B-2707 Inlet Flow Field Model

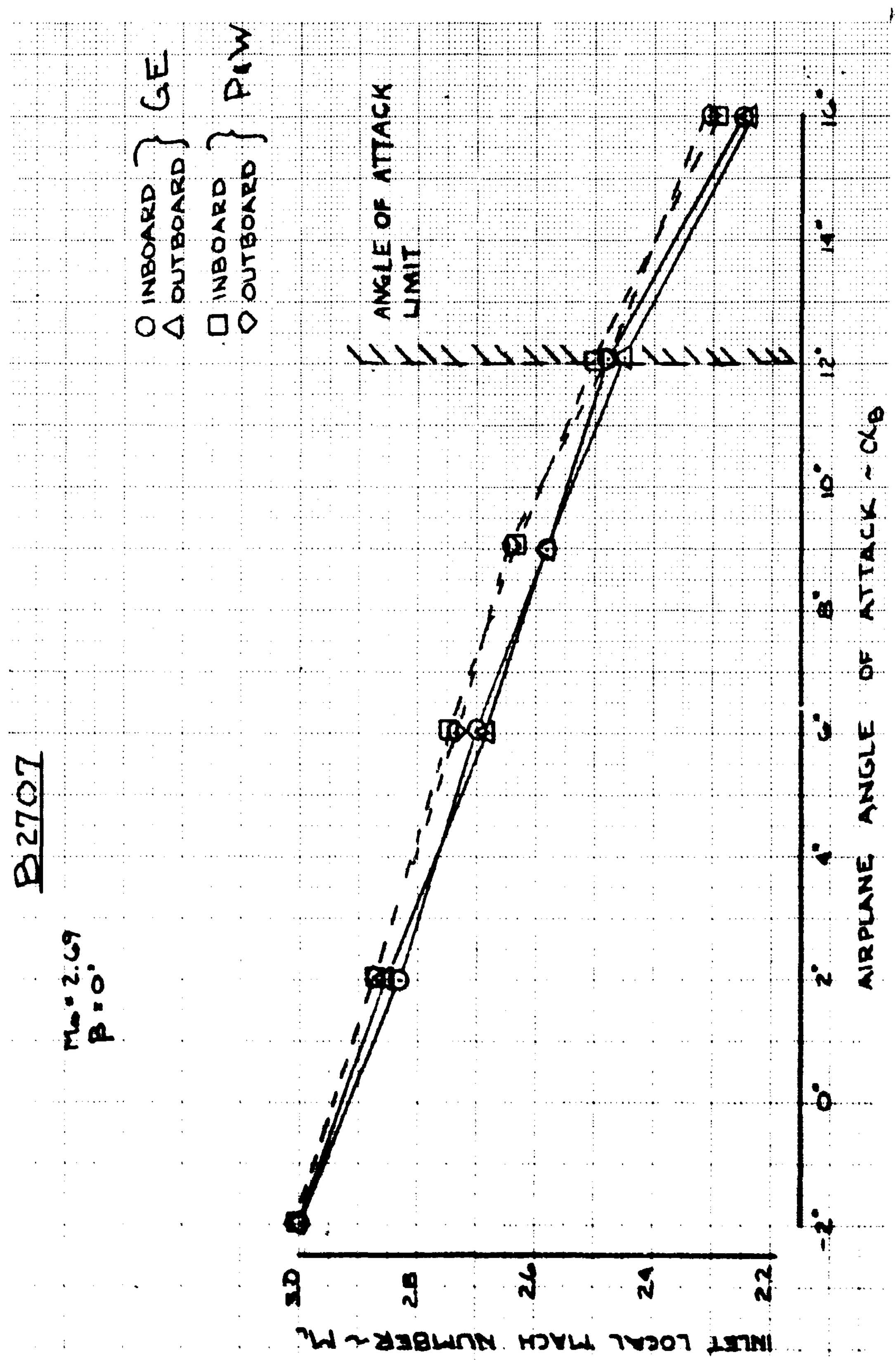


Fig. 44 Angle of Attack Effects On Local Inlet Mach No.

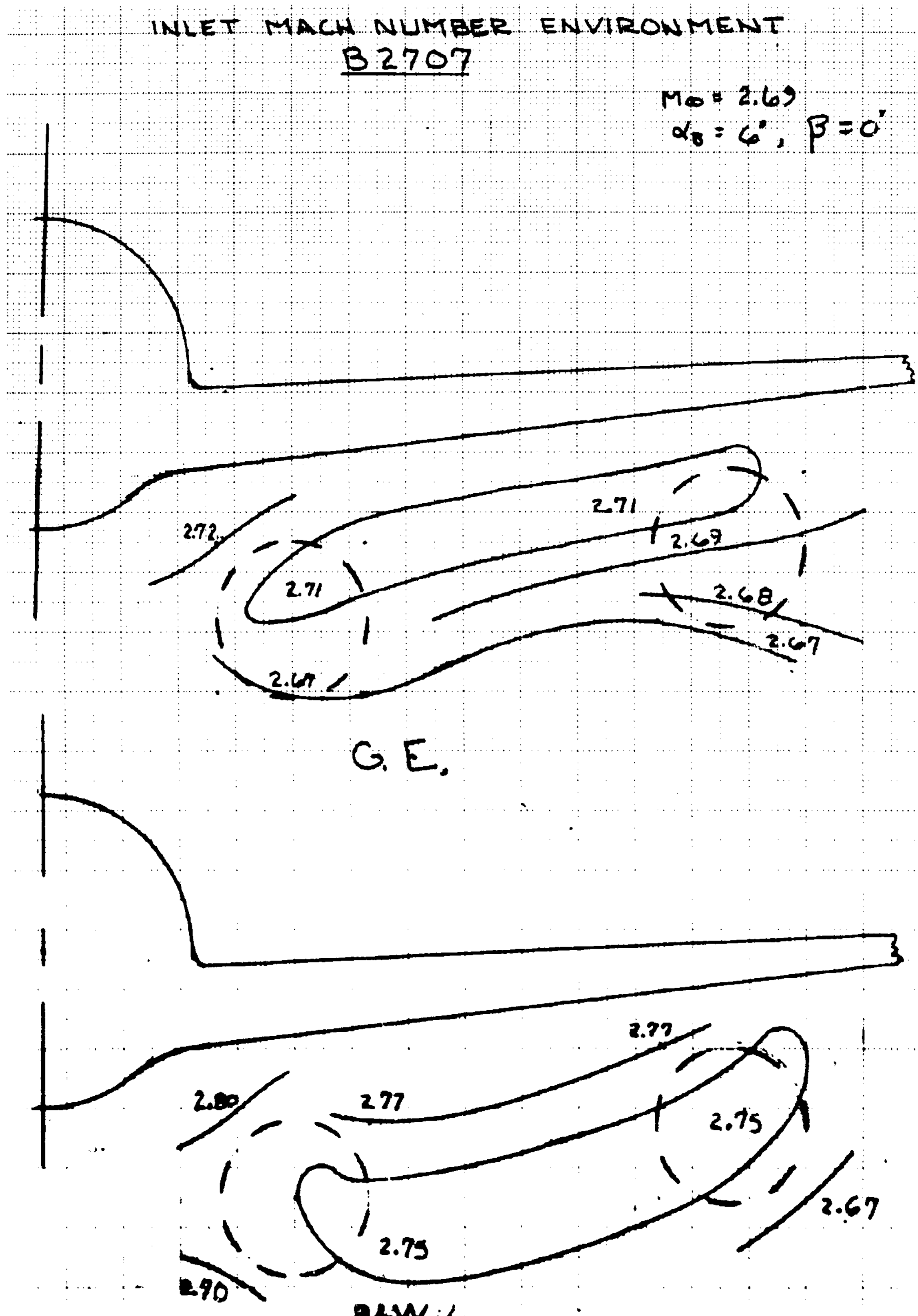


Fig. 45 Inlet Face Mach No. Gradients

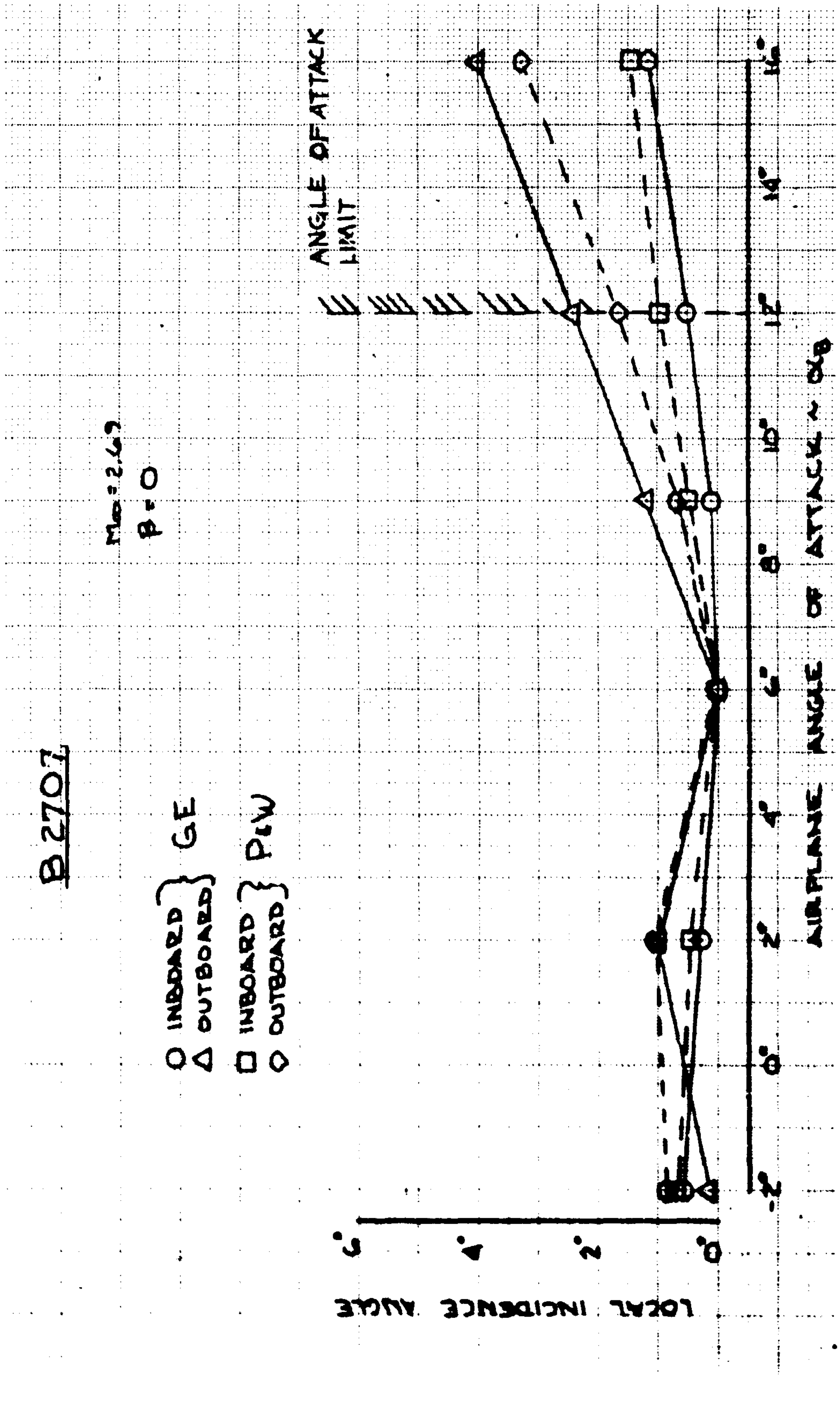


Fig. 46 Angle of Attack Effects On Inlet Incidence Angle

III. Description of Technical Progress (continued)

1302. Air Induction System (continued)

(b) 1/5 Scale Inlet Model Vortex Valve Stability System Performance Testing

Dynamic data results from the 1/5 scale model tests (with vortex valves installed) are shown in Fig. 47. These data are in addition to those shown to the FAA evaluators during the on-site inspection in September. The figure shows oscillograph traces with the inlet operating at $M_o = 2.57$ with vortex valves installed and subjected to a simulated downstream disturbance. The plug valve flow area downstream of the compressor face was decreased at a rate resulting in approximately a 250 percent decrease in engine corrected weight flow per second from 2 percent supercritical to critical. The oscillograph trace shows the plug being stepped from 2 percent supercritical to critical in approximately 0.03 seconds with an engine-corrected weight flow decrease of approximately 7.5 percent. Figure 48 shows steady-state cowl wall static pressures for 2 percent supercritical, 1 percent supercritical, and critical conditions. The station locations of the cowl wall static pressures shown on the oscillograph trace are indicated on Fig. 48. The static pressure pickup PCS 12, is positioned approximately in the center of the main bleed throat slot.

The vortex valve centerline pressure shown on the trace, indicates the weight flow through the vortex valve. This pressure is measured on the centerline of the vortex valve exit nozzle.

The oscillograph traces indicate that the normal shock travel is slowed down due to the vortex valves bypassing inlet air. After the plug step, which initiates the shock movement, there is an initial rapid pressure increase across PCS 12. As the vortex valves start to bleed, however, the normal shock propagation rate is decreased until maximum stability limits are attained. The location of PCS 12 is midway between PCS 14 and PCS 10. The time interval between the normal shock passage between PCS 14 and PCS 12 is 0.003 seconds while approximately 0.098 seconds elapses between PCS 12 and PCS 10. This indicates the average normal shock propagation velocity was attenuated by a factor of 32.7.

Figures 49 and 50 are pictures of the vortex valve stability system installed in the 1/5 scale inlet model and Figs. 51 and 52 show the vortex valve assembly and detail parts.

(c) Test Schedule

Figure 53 shows the schedule of various propulsion testing through December 1966.

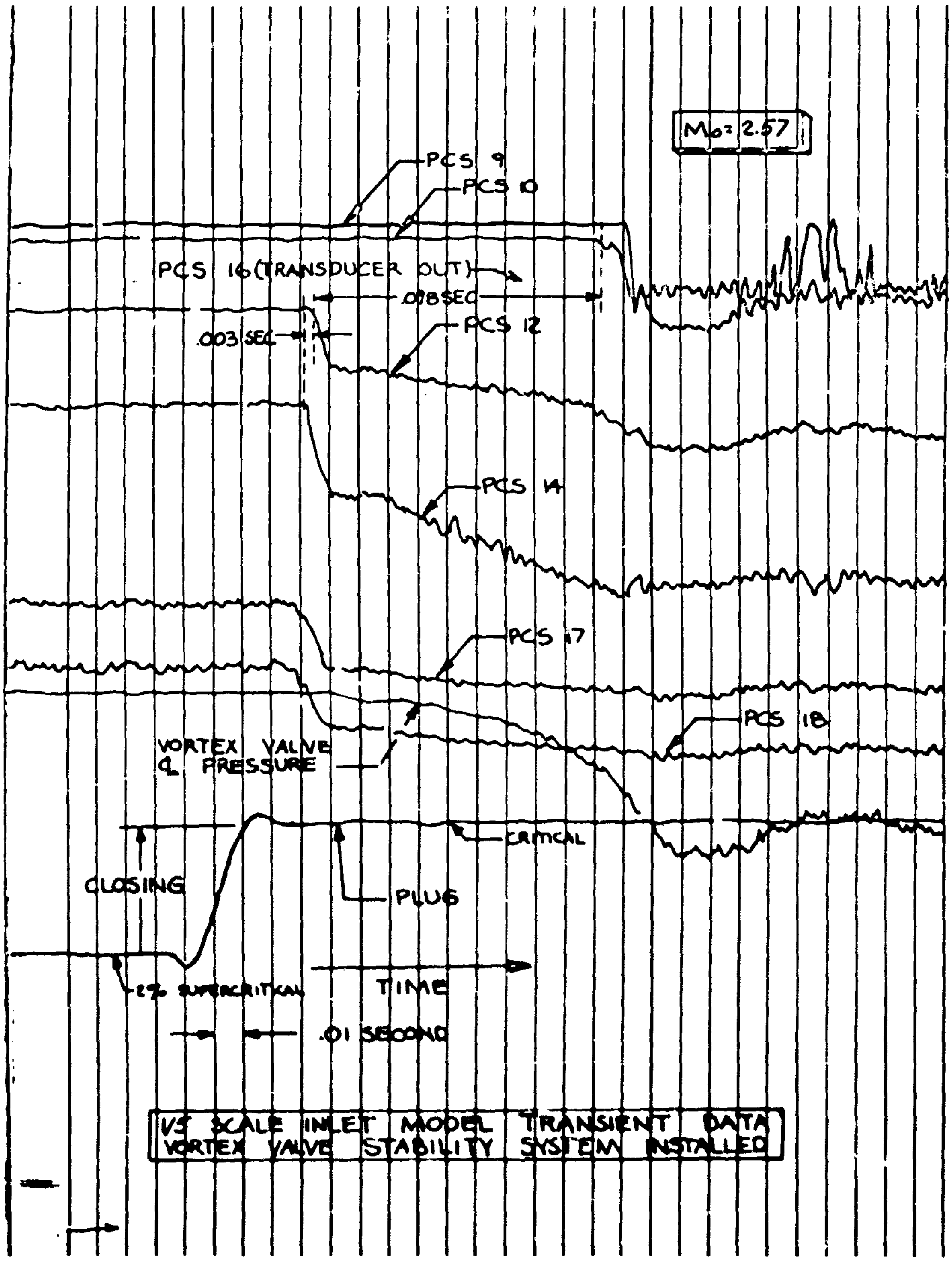


Fig. 47 1/5-Scale Inlet Model Transient Data Vortex Valve Stability System Installed

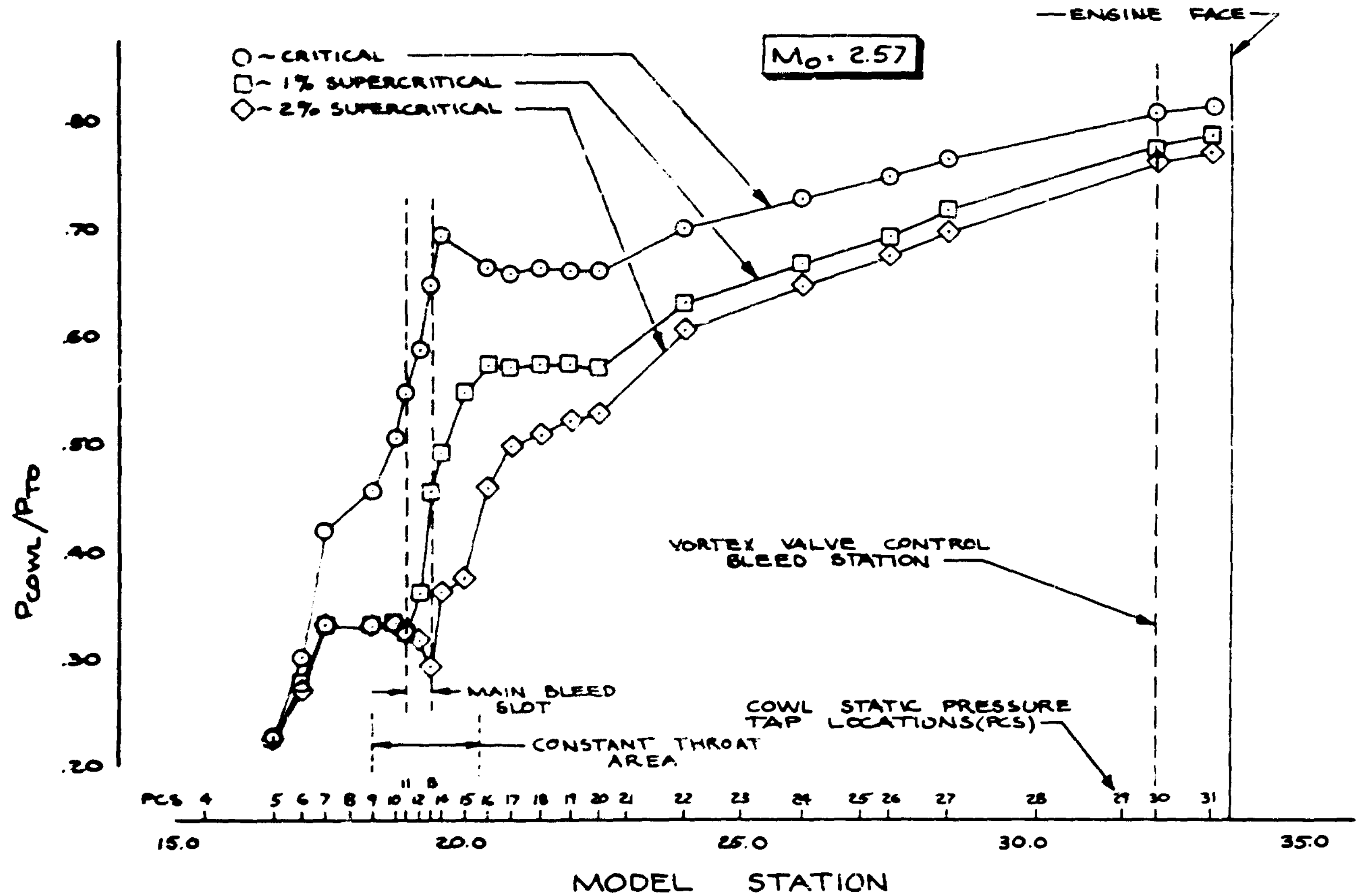


Figure 48. Cowl Static Pressure Profiles For 1 5-Scale Inlet Model With Vortex Valve Stability System Installed

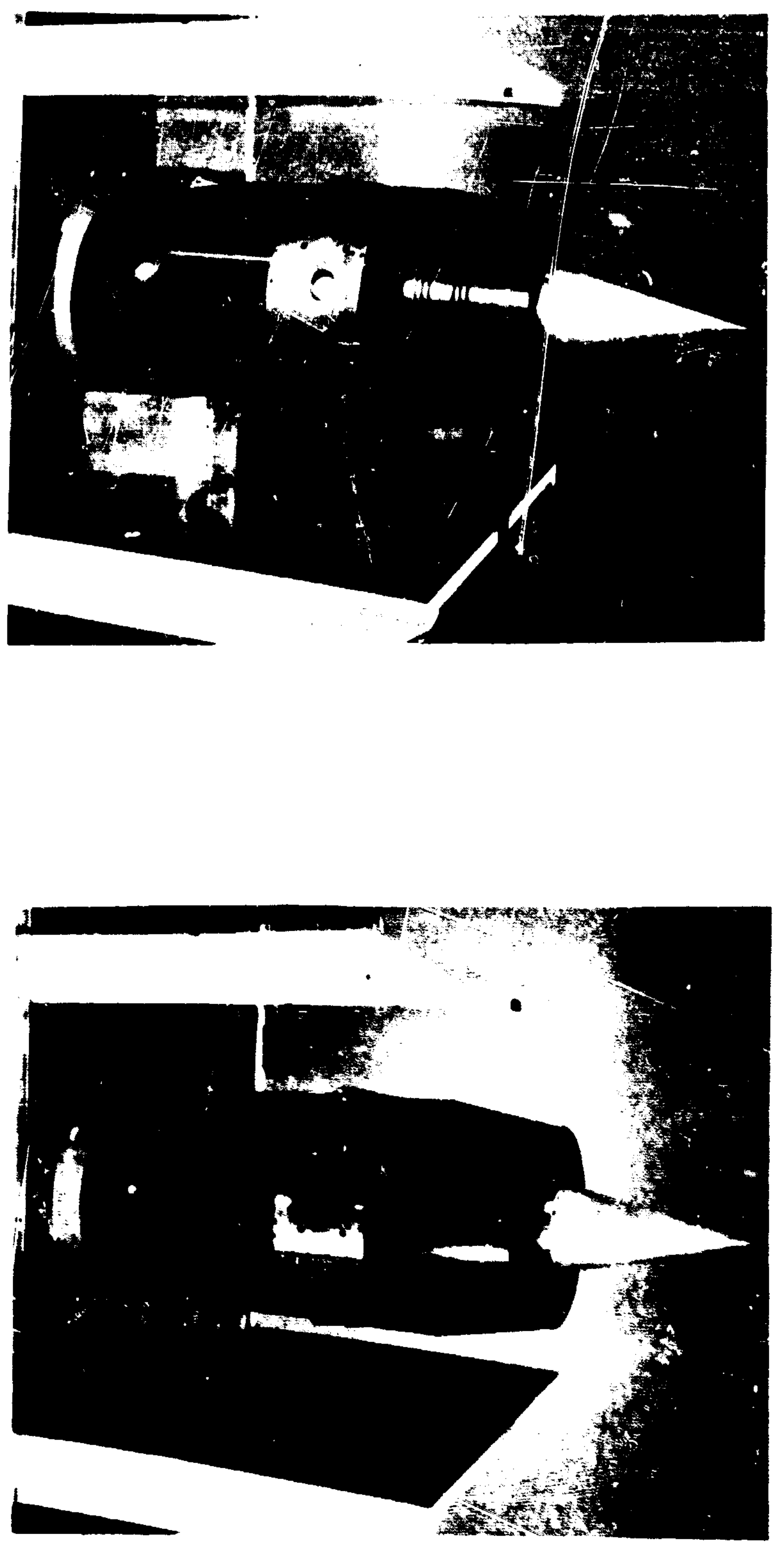
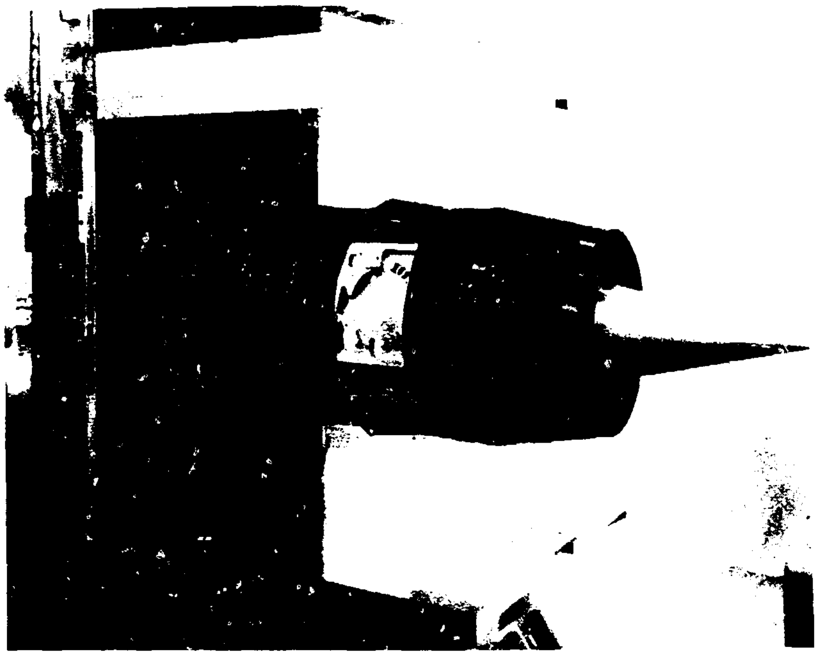


Fig. 49 1/5-Scale Inlet Model With Vortex Valve Cover Removed (upper) and Valves Installed (lower)



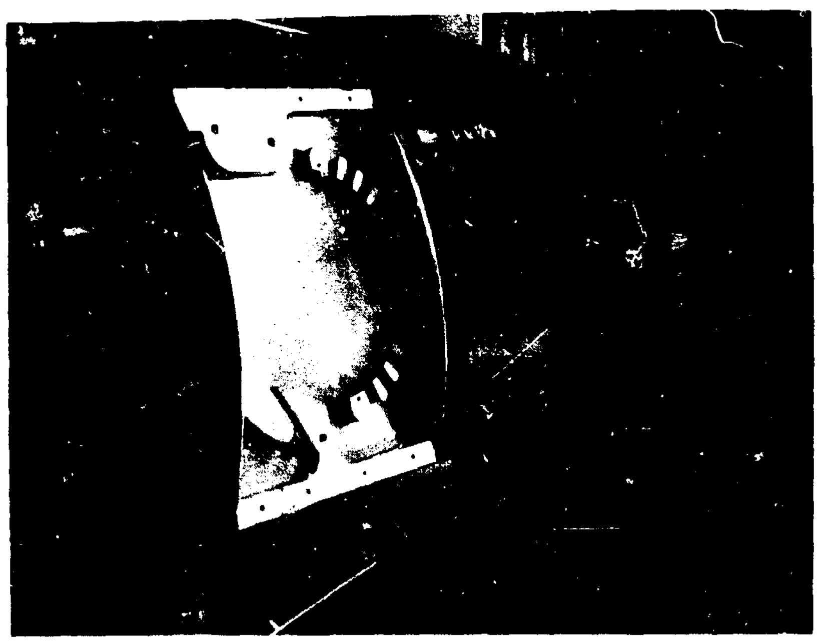


Fig. 50 Vortex Valve Chamber On 1/5-Scale Inlet Model

Fig. 51 1/5-Scale Inlet Model Vortex Valve

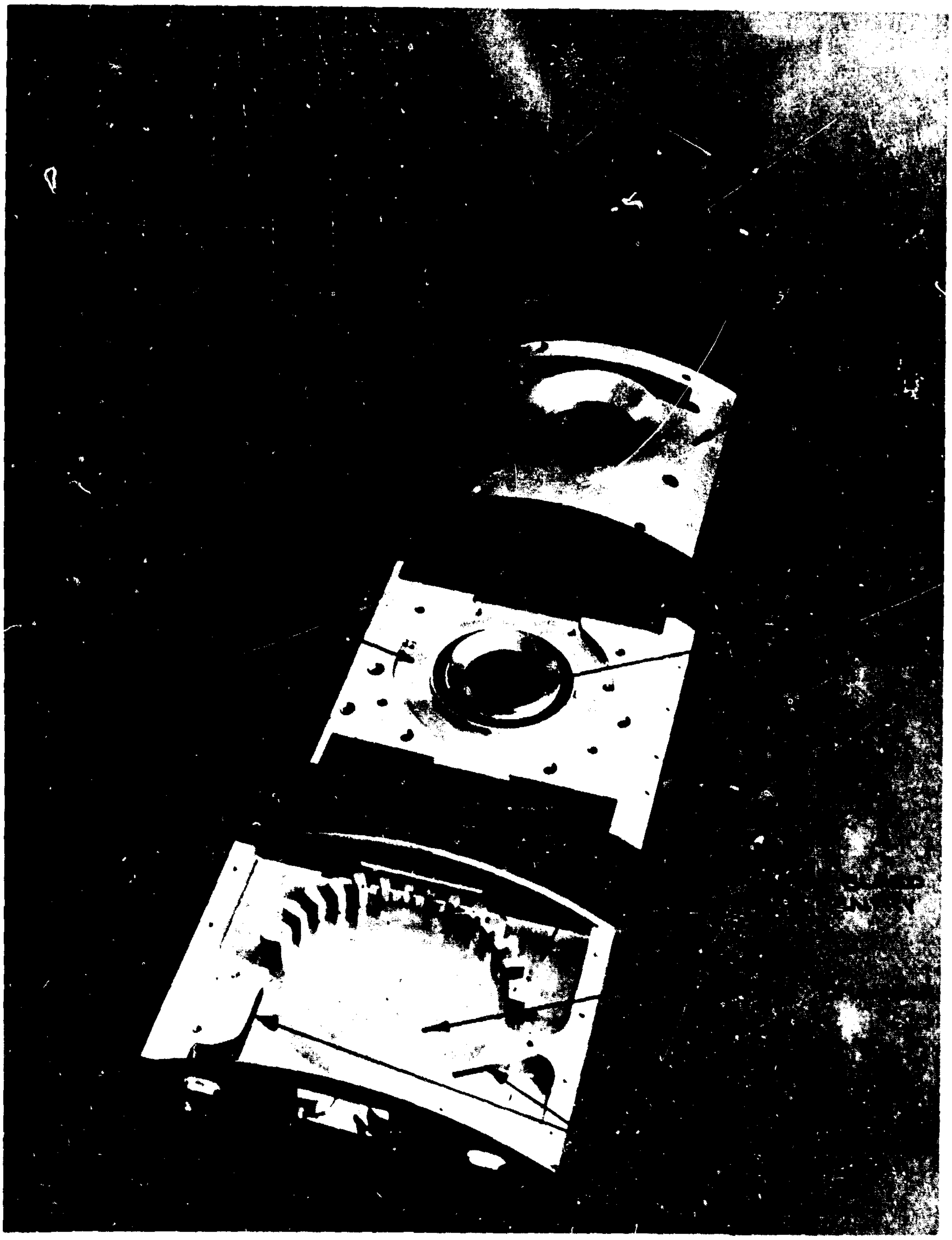
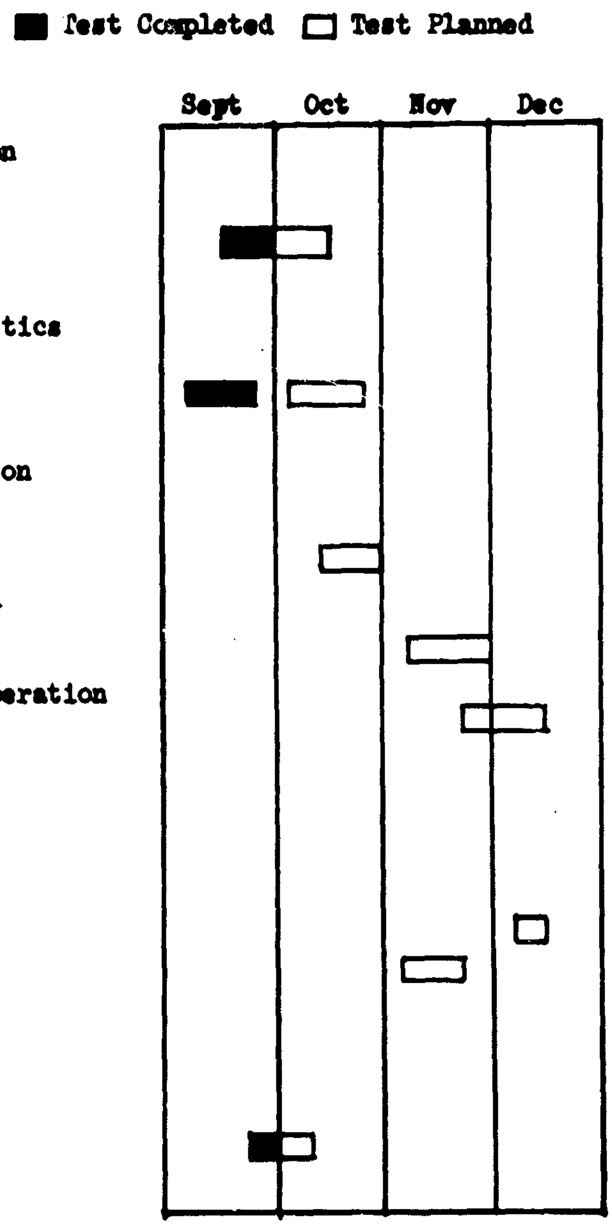


Fig. 52 1/5-Scale Inlet Model Vortex Valve

MODEL DESCRIPTION



Fluid Control for Stability Bleed Augmentation
Inlet Throat Vortex Valves
Facility: 18 x 18 inch VN Tunnel
1/5 Scale Inlet with Vortex Valves

Inlet Buzz Stability and Starting Characteristics
3 inch Inlet
Facility: 6 x 6 inch VN Tunnel

Inlet Performance and Control System Evaluation
1/5 Scale Model
Performance and Control Signals. Fixed
Geometry Performance
Variable Diameter Centerbody, Performance and
Control Signals. Variable Centerbody and
Bypass System
Control Signal Study and Analog Controller Operation
Control Dynamics Test
Facility: 18 x 18 inch VN Tunnel

Takeoff; Inlet Choked Model Testing and
Inlet-Airframe Low-Speed Compatibility Tests:

1/10 Scale - Takeoff, Noise, B2707 Config.

1/3 Scale Inlet - J85 Engine Test

Facility: 9 x 9 foot Low Speed Tunnel

Reverser Ingestion Test
1/20 Scale Airplane Model
Facility: 9 x 9 foot Low Speed Tunnel

Fig. 53 Propulsion Testing Schedule

1303. Air Induction Control

(1) Simulation Studies

The inlet mathematical model used for inlet-engine compatibility study has been updated to include the vortex valves and to represent the new steady-state operating condition with 1 percent stability margin and 1.25 throat Mach number. Selected simulation runs are being made to investigate the effect of vortex valves on the inlet transient.

A separate mathematical model is being synthesized to represent the 11.24-inch lip diameter, variable geometry inlet model that is being tested in the wind tunnel. This mathematical model will be used to simulate the wind tunnel test runs to examine the validity of the simulation method.

(2) Wind Tunnel Tests

The first phase of the 11.24-inch lip diameter, variable centerbody inlet control signal and centerbody control loop tests have been completed.

The results of the control signal tests confirmed earlier finding that proper selection of control signals will allow use of constant reference signals for the centerbody and normal shock control loops. A limited number of inlet control signal tests with vortex valves installed was also included in this phase. No changes in signal characteristic were noticed due to vortex valves, except increased margin in corrected engine flow between control set point and critical point. A test result is presented in Fig. 54.

The centerbody control loop test was conducted in two parts: first, using an all-purpose analogue computer (Applied Dynamics Inc. Model AD-2-32PB) to simulate the centerbody control loop and, second, using a breadboard electronic inlet control made by Boeing. Imposed inputs were tunnel Mach number and inlet angle of attack in forms of ramps and sinusoids at the tunnel Mach numbers from 2.0 to 2.6.

The inlet has been successfully controlled with both the analogue centerbody control and the electronic control units during a ramp change in Mach number with a rate as high as 0.4 Mach/sec., and a ramp change in angle of attack with a rate as high as 4 deg/sec. Similarly, control has been demonstrated during sinusoidal Mach number and angle of attack changes through the range shown in Fig. 55.

The second phase of the 11.24-inch inlet test will include additional control signal tests, normal shock control loop tests, and combined centerbody and normal shock control loop tests.

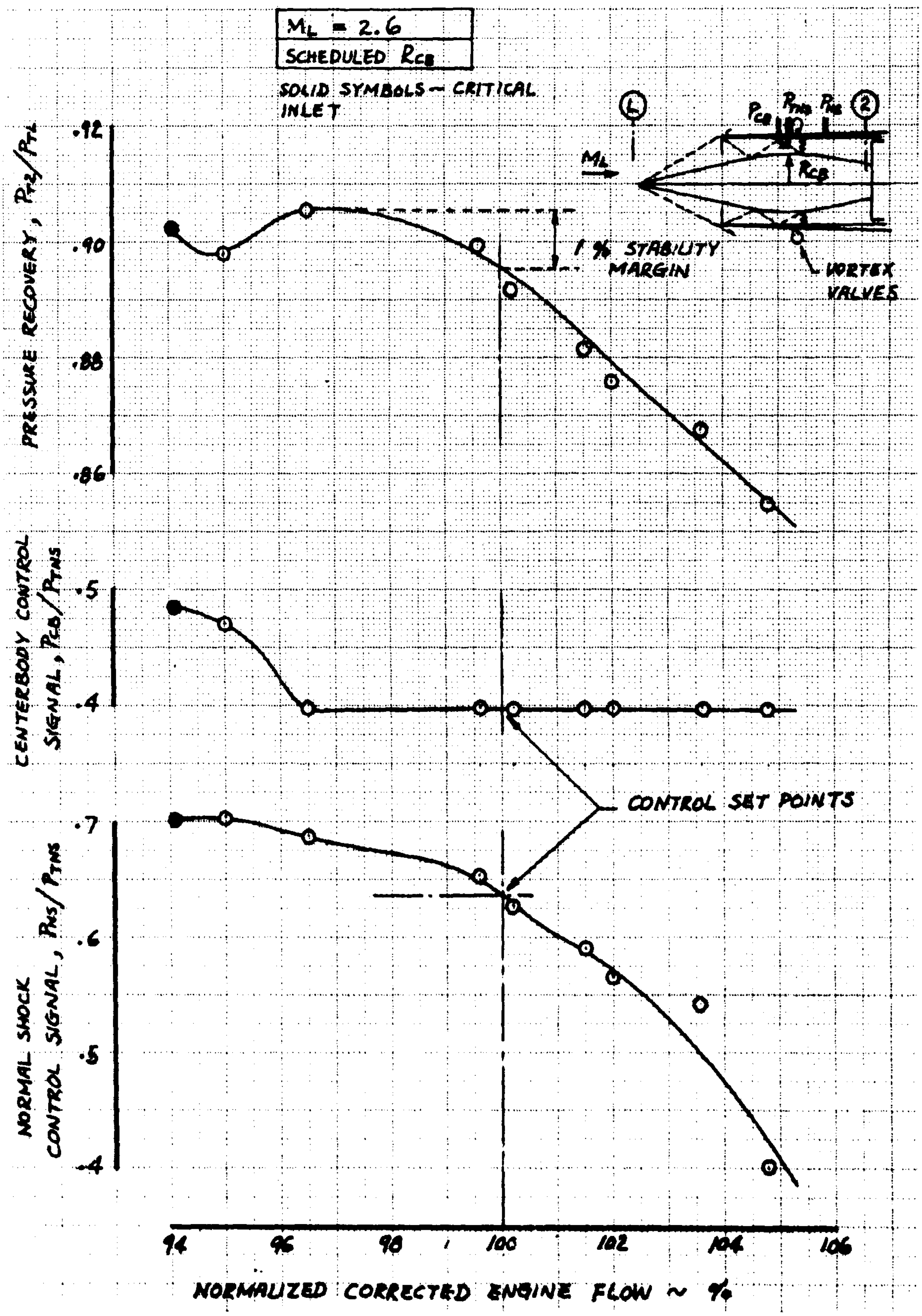


Fig. 54 Inlet Pressure Recovery and Control Signals Versus Corrected Flow – 11.24-In.

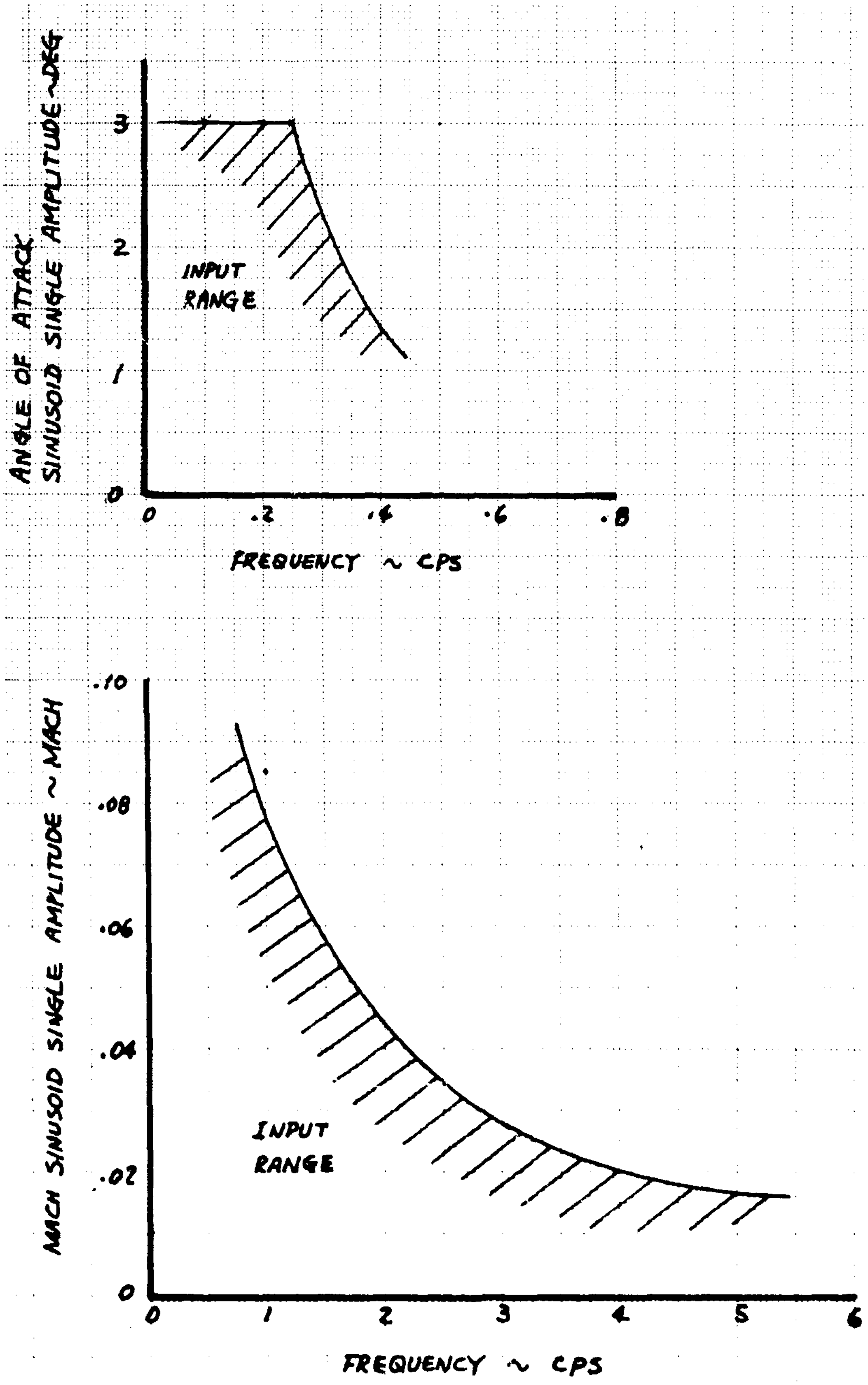


Fig. 55 Ranges of Sinusoidal Inputs Used for Centerbody Control Loop Tests

1304. Propulsion Controls

The propulsion control operation criteria was established and defined in D6A10113-1 "Aircraft Engine Installation Subsystem Specifications", page 9 on 9-6-66.

The propulsion control system was defined in document V2-B2707-12, Propulsion Report - Part A, Engine, Inlet and Controls; and D6A10113-1 "Aircraft Engine Installation Subsystem Specification" on 9-6-66.

1305. Propulsion Installation

The propulsion pod drain system was reviewed with the engine manufacturers and the configuration agreement is included in the Engine/Airframe Technical Agreements D6A10198-1 and D6A10199-1.

Document D6A10113-1 "Aircraft Engine Installation Subsystem Specification" was updated on 9-6-66, bringing the definition of the system requirements up to date.

Document 60A10031 "Thrust Indicating System" was released 8-1-66 defining the requirements for a direct reading thrust measurement system.

The engine instrumentation has been established and included in document V2-B2707-13, Propulsion Report - Part B, released 9-6-66.

1306. Fuel System

Fuel Subsystem Specification D6A10116-1 was completed and submitted to the FAA on September 6 as a part of the Phase III proposal.

Fuel Tank Inerting Study - Supersonic Transport, D6A10332-1 and Fuel System Analysis - Supersonic Transport Phase II-C, D6A10333-1 were released on September 16.

Thompson-Ramo-Wooldridge Accessories Division has completed the assembly of the first test boost pump and started development testing. Boeing review team witnessed first teardown inspection of the test unit during the last week of September. The pump was in good condition.

Fuel Selection for The Boeing Supersonic Transport, D6A10329-1 was released on September 15. Commercial aviation kerosene (ASTM D-1655-64T Jet A and A-1) has been selected for the B-2707 SST.

1307. Exhaust/Reverser System

(1) Installed Nozzle Performance Test

An initial installed performance test was conducted in the Boeing transonic wind tunnel during August. A wing was mounted on an existing forebody, and Phase IIA P&WA blow-in-door ejector and GE long-flap ejector nozzle models were tested. The wing-nacelle relationship was compromised in order to use existing models; as a result, the wing did not reflect the true B-2707 reflex.

Figure 56 is a picture of the P&WA transonic nozzle test installation. Figure 57 shows the uninstalled thrust coefficient data for P&WA subsonic and transonic models as well as data from a previous test for comparison purposes. The P&WA transonic (M=1.2, Max. D/H) model was tested with the blow-in-doors full open and closed. Data for the GE nozzle is not shown, since the model tested was a long-flap ejector nozzle, instead of their proposed Phase III blow-in-door ejector nozzle. Figure 58 shows an incremental thrust coefficient defined as $\Delta C_F = C_F$ (with wing) - C_F (w/o wing). Thus the incremental thrust coefficient reflects the gross installation effects on both the wing drag and nozzle performance. The incremental thrust coefficient due to wing effect is essentially zero. The accuracy of the incremental thrust coefficient is estimated to be ± 1 percent.

Tests will be conducted with revised wing reflex and updated exhaust nozzle configurations to determine the effect on nozzle performance.

(2) Requirements Established

The thrust reverser performance and operational requirements were established and included in documents D6A10198-1 and D6A10199-1 "Engine/Airframe Technical Agreement" released 9-6-66.

13073 NOZZLE SECONDARY AIR

The secondary air pressures and flow schedules were received from the engine contractors and included in document V2-B2707-13.

1308. Noise

Large scale models of promising suppressors are shown in Figs. 59, 60 and 61.

The initial test phase objective is to establish the performance characteristics of the suppressor concepts. Preliminary test results indicate that the model test data and the large scale data correlate very well. Figure 62 shows the performance data for the chute/scoop ejector with the J75 in afterburning compared to the model scale data.

Fig. 56 P and WA. Transonic Nozzle Test Installation

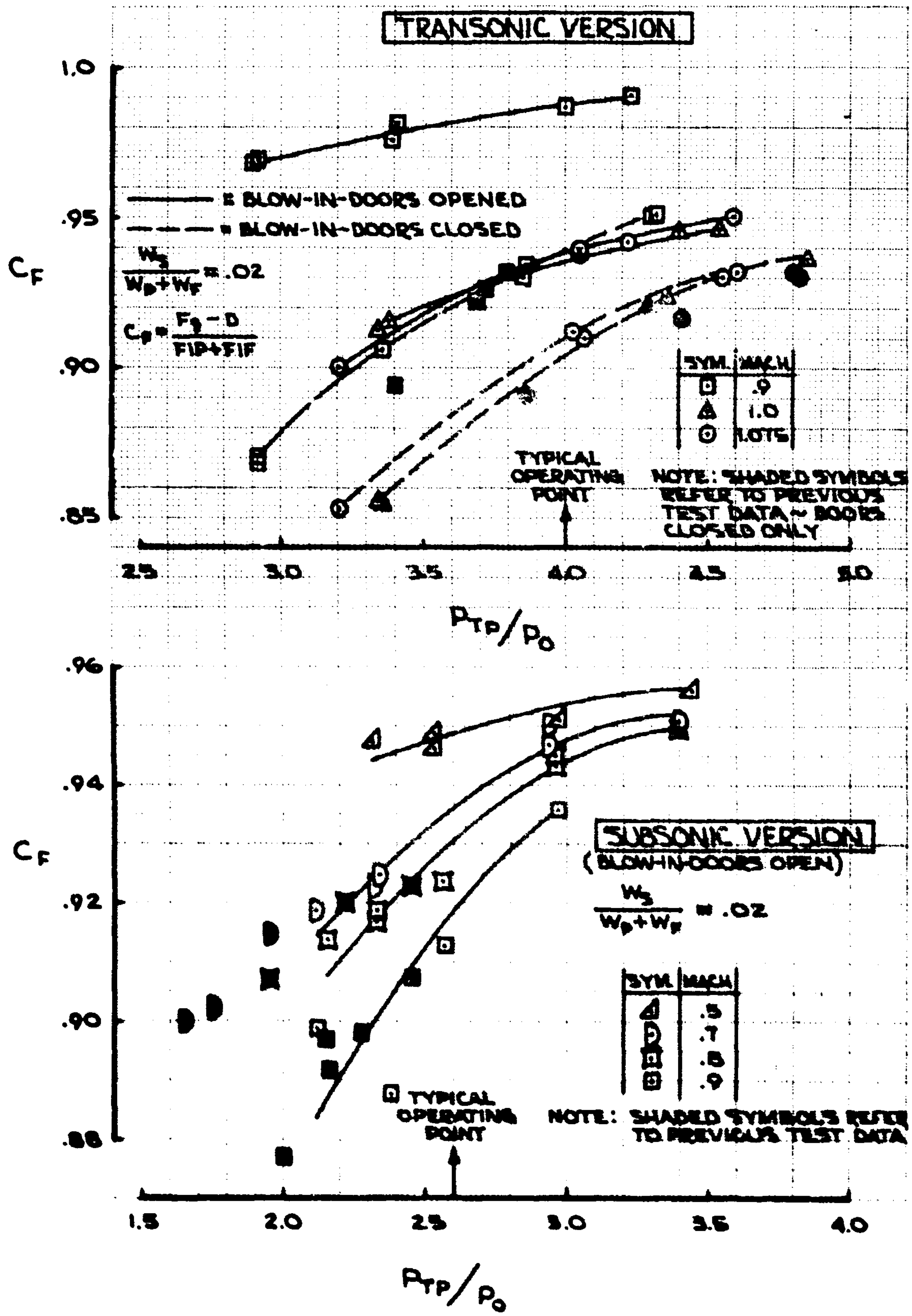


Fig. 57 Uninstalled Nozzle Thrust Coefficient – P and WA Blow-In Door Ejector Nozzle

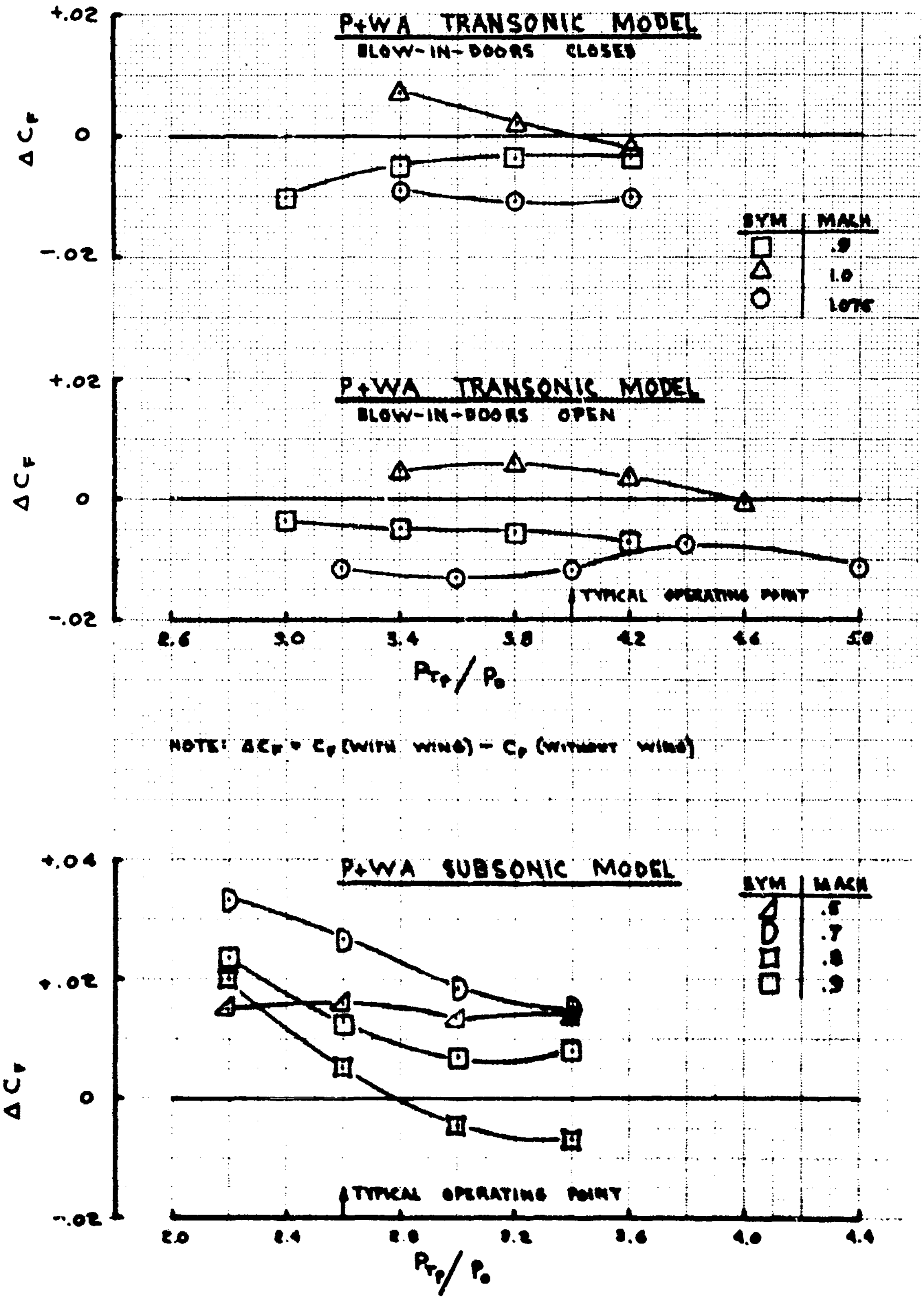


Fig. 58 Nozzle Thrust Coefficient Effect Due to Wind Installation

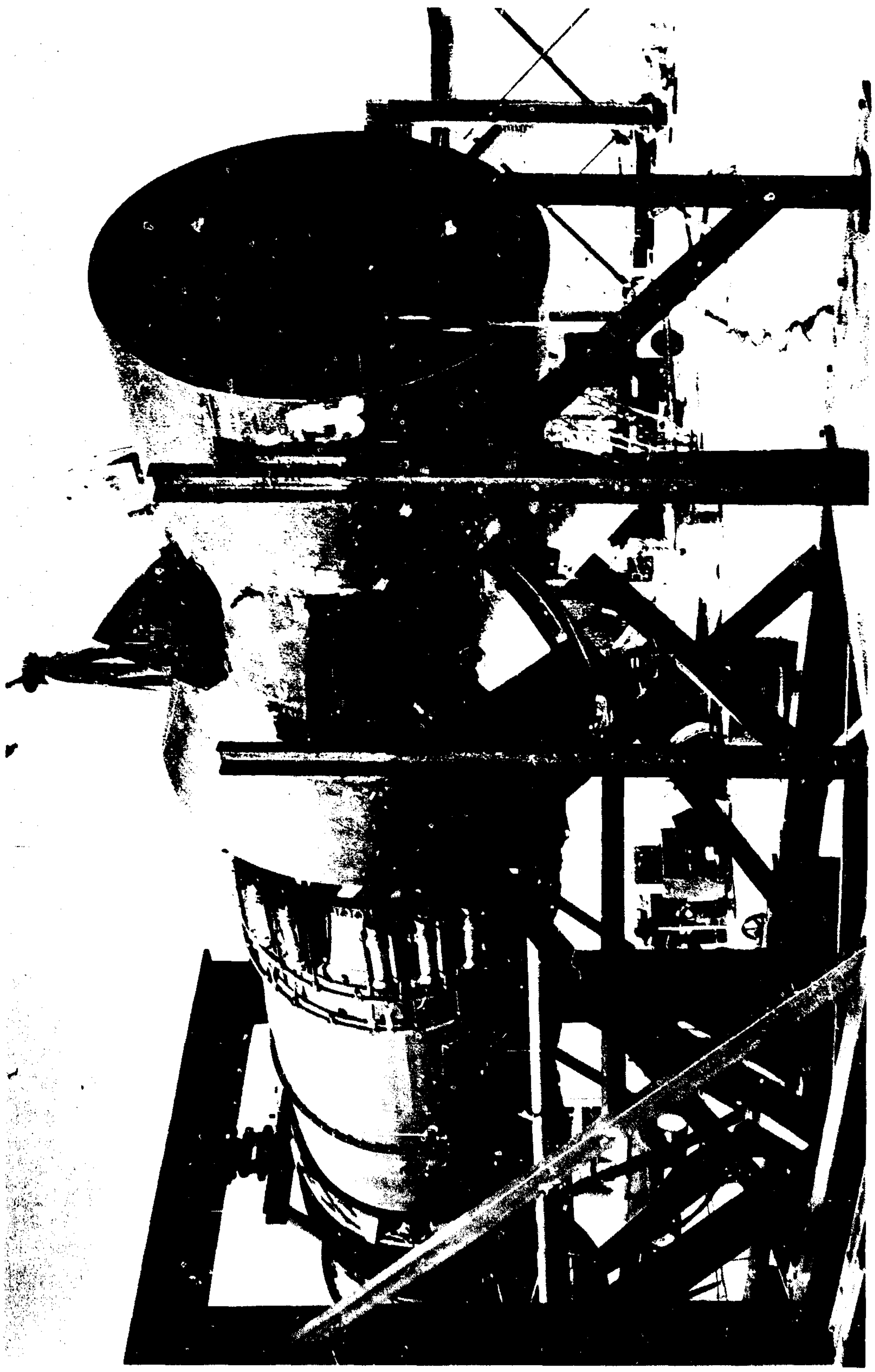


Fig. 59 J-75 Engine With Afterburner and Chute/Scoop Ejector

Fig. 60 Chute Ejector

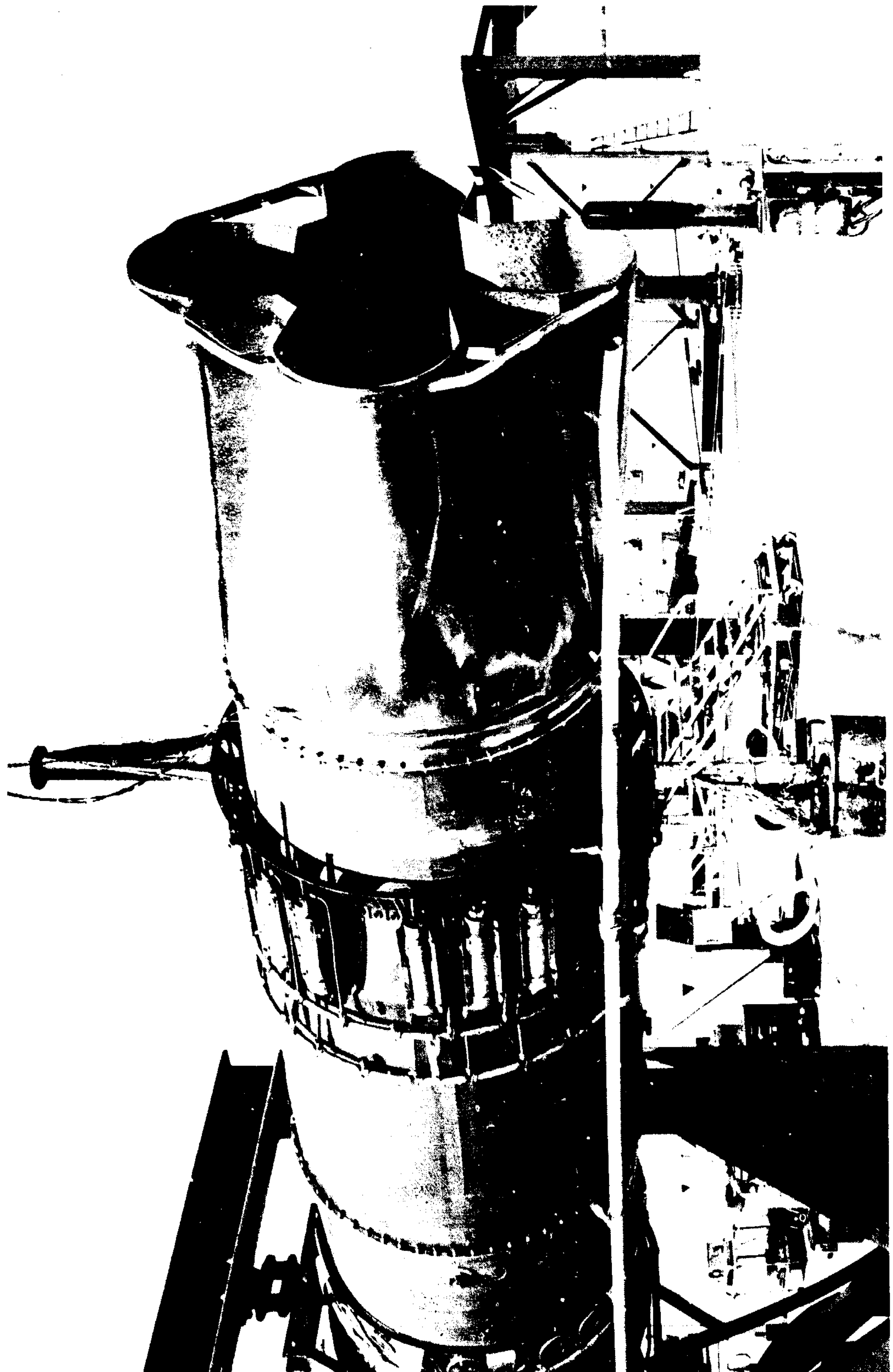


Fig. 61 J-75 Engine With A/B Four-Lobed Nozzle

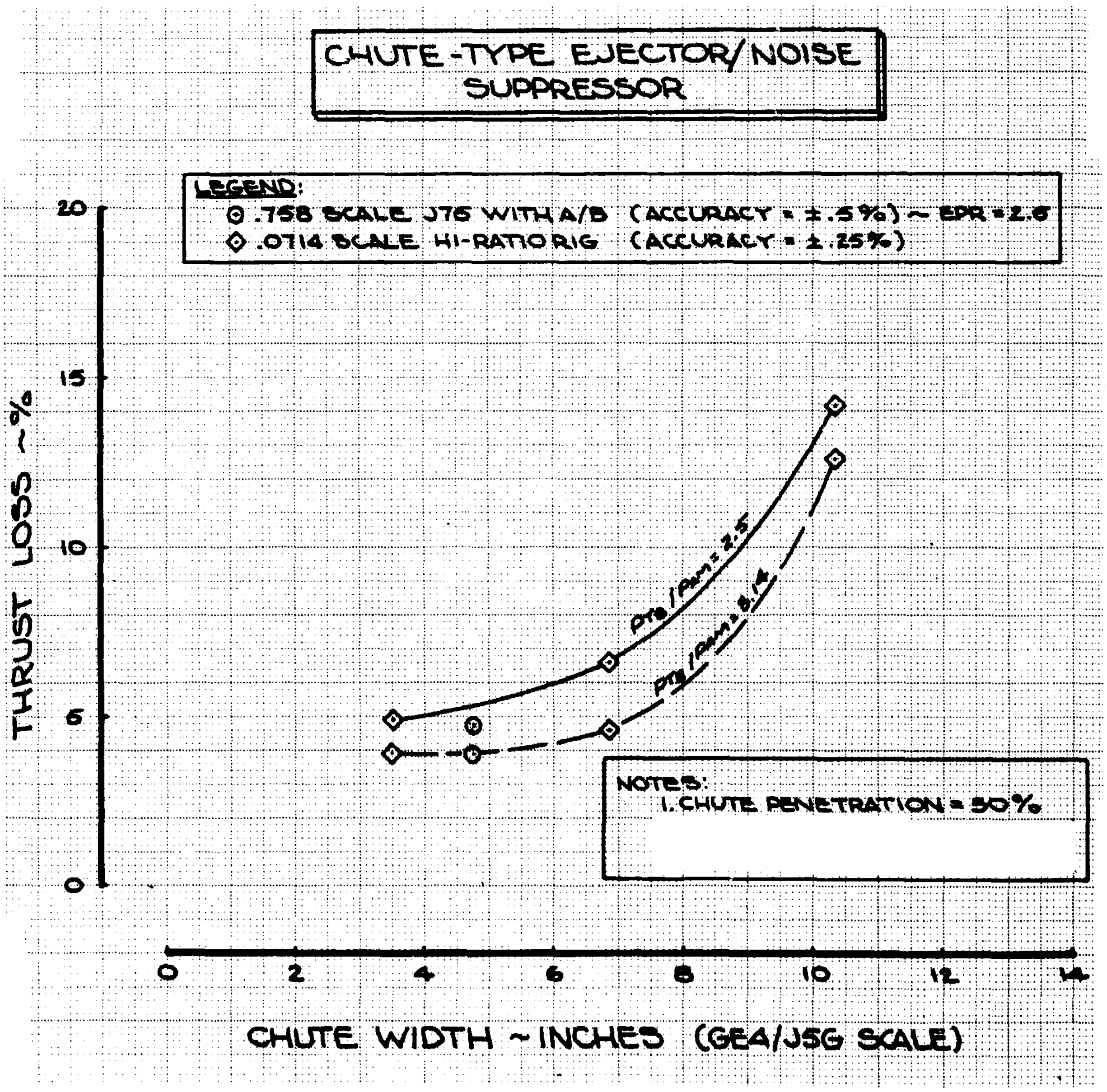


Fig. 62 Model and Large-Scale Performance Comparison

1309. Engine Coordination

On September 9, P&WA personnel presented a technical review of steady state and transient distortion test results, analysis and measurement techniques connected with recent engine development programs.

Pratt and Whitney Aircraft personnel were at Boeing September 26 through September 28 to discuss engine control operation and mathematical simulation for inlet-engine compatibility studies. Extension of the engine mathematical model to include fan and compressor stall and recovery, duct heater and gas generator blow-out logic and inlet distortion effects was discussed. Agreement was reached regarding information required by P&WA and Boeing for further inlet-engine compatibility studies.

Documents D6A10198-1 and D6A10199-1 "Engine/Airframe Technical Agreement"were released 9-6-66. These documents define the responsibilities of engine manufacturers (Pratt and Whitney or General Electric) and the airframe manufacturer (Boeing) for the physical, functional and program requirements of the engine/airframe system.

14. PRODUCT SUPPORT

1400. Product Support – General

Maintenance Engineering

Maintenance engineering participated in a maintainability presentation and conference at American Airlines, Tulsa, on September 15. and airport operators conference held in Seattle on Sept. 26.

1401. Data and Handbooks

14010 DATA AND HANDBOOKS GENERAL

Phase II-C Task No. 1401, b, 1, reflected in the Detailed Work Plan, D6-18139, p. 51, requires "Complete Preliminary Flight Crew Operating Procedures," on August 31.

In fulfillment of the above requirement, D6A10272-1, entitled "Preliminary Flight Crew Operating Procedures for B-2707 Airplane," was released by the Product Support Section on August 24.

1403. Training and Training Equipment

14030 TRAINING AND TRAINING EQUIPMENT GENERAL

(1) Training Analysis and Study Activities

(a) Using the crew work load analysis data, the initial study of flight crew functions of a generalized supersonic flight profile from engine start through supersonic cruise to post flight shutdown was completed.

III. Description of Technical Progress (continued)

14030 Training and Training Equipment General (continued)

From this study preliminary flight crew ground training, flight simulation, and flight training requirements data were further refined.

(b) Training objectives of each of the training functions and the training activity required to achieve such objectives are being established as a basis for the training method and media trade studies and recommendations. More specific requirements for flight crew training equipment and the flight simulator are being established.

(c) At the suggestion of the training personnel of certain airlines, and to provide a better appreciation and knowledge of line operations, a program of line crew observations during actual line flights has been initiated. These are being performed on flights on which training personnel are making trips for other purposes. Through coordination with the airlines, cockpit passes have been obtained for flights with two different carriers. Typical of the information of interest are observations and crew comments relative to crew routines, crew comfort, subsystem operation, crew work load, air route traffic control, and crew scheduling practices.

(d) A representative of the flight crew training and equipment requirements group attended a symposium sponsored by Link Group of General Precision, Inc., to review the status of flight simulation in commercial aviation. Representatives from 23 U.S. and foreign airlines and related companies were present. The agenda covered the history, capability, and future direction of simulation in support of commercial airline operations. The area of primary interest to the SST training representative was current and future development programs which might support the SST training flight simulator design and crew training requirements. It was apparent that a concerted effort will be necessary in conjunction with the simulator industry, to advance the visual and motion capabilities of the simulator if these devices are to come up to the desired fidelity for SST flight crew training.

(2) Training Curriculum

(a) Procedures for development of curriculum have been formulated as a guide for use in course development has been prepared. This guide will assure a standardized approach and provides a checklist for the orderly sequencing and accomplishment of all steps necessary for proper curriculum development. These procedures and the guide are being applied initially in the flight crew training courses development on a test basis to validate the procedures or refine them as experience dictates.

1404. Ground Support Equipment

14040 GROUND SUPPORT EQUIPMENT - GENERAL

The Ground Support Equipment Requirements Specification, document number D6A10180-1, which contains the GSE general design requirements, a consolidated list of GSE arranged by airplane systems, and GSE item specification sheets, was completed and submitted as part of the Phase III proposal.

A Ground Support Equipment Program Plan was prepared and submitted as part of the Phase III Product Support Program proposal, document V4-B2707-20. The GSE Plan describes the program for identification, development, and integration of the GSE hardware and data required to support the B-2707 prototype and production airplanes. A presentation of the planned GSE program was made to the Product Support team during the on-site evaluation, September 19 to 23.

14041 SERVICE GROUND SUPPORT EQUIPMENT

The engineering analysis of the airplane ground handling and service requirements was completed and the results are reported in the Operations Suitability document, V4-B2707-1, of the Phase III proposal.

One-hundredth-scale models of an air terminal, B-2707 airplanes, and ground support equipment were made to demonstrate ground handling and service techniques for the supersonic transport.

Engineering studies were initiated for alternate solutions to special requirements such as aft galley servicing and hand loading of baggage.

14042 MAINTENANCE GROUND SUPPORT EQUIPMENT

The analysis of the SST for major definable Maintenance GSE requirements was completed and information was prepared for inclusion in the GSE Requirements Specification. Twenty detail performance/design specifications for major items of GSE were completed and released prior to the on-site evaluation.

New engineering studies on engine handling and transport, airplane ground movement, airplane weighing, jacking and accident recovery, and on maintenance platform and equipment requirements for airplane overhaul have been initiated. The application of a general purpose, semi-automatic or automatic test system for shop test of major avionic systems is being investigated.

1405. Facilities

14051 AIRPORT COMPATIBILITY

The Airport Compatibility Report for Phase II-C was completed and submitted on September 1, 1966. This report included document D6A10317-1, "Airport Pavement Requirements for the Boeing Supersonic Transport Model 2707," and a detailed evaluation of compatibility with the 15 designated international airports. This report substantiated the high degree of compatibility between the B-2707 and the airports investigated.

IV AIRLINE COORDINATION

Personnel from the Airline Pilots Association and the following airlines were given mockup tours and technical briefings:

Air Canada
Ansett Ana
Pan American Airways
Sabena Belgian World Airlines
South African Airways

Detailed design discussions were also held with Air Canada and Qantas Empire Airways. The briefings were arranged to assist these airlines in supplying the FAA with non-U.S. airline evaluations of the Boeing SST.

Detailed engineering briefings were presented during visits to the following airlines:

Air France
Alitalia
British Overseas Airways
Eastern Air Lines
El Al Israel Airlines
Irish International Airlines
KLM-Royal Dutch Airlines
Lufthansa German Airlines
Pakistan International Airlines
Sabena Belgian World Airways
Scandanavian Airlines Systems
Swissair

Non-U.S. Airlines Symposium

On September 27, 28, and 29, 1966, approximately 130 management, technical and operating personnel of 26 non-U.S. airlines visited Boeing in Seattle, to become acquainted with the Boeing proposal for Phase III preproduction prototype construction and the follow-on production program. Airlines represented were:

Air Canada
Air New Zealand
Air France
Air India
Alitalia
British Overseas Airways
Canadian Pacific
El Al Israel Airlines
Iberia
Irish International
Japan Air Lines
KLM
Lufthansa
Pakistan International Airlines
Olympic Airways
Qantas Empire Airways
Sabena Belgian World Airways
Scandinavian Airlines System
South African Airlines
Swissair
TAP (Portugal)
UTA (France)
Viasa (Venezuela)
Varig (Brazil)

IV. Airline Coordination (continued)

Customer Engineering coordinated the agenda for the symposium and arranged and conducted tours of the SST Mockup, Technical Briefing Area and Product Display. In addition, arrangements were made for detail technical discussions, as desired by individual attendees, including visits to, and operation of the two flight simulators. Personnel from appropriate design, technical staff and support organizations were called on to provide desired information to airlines personnel.

The recommendations presented during the June 1966 meetings with the U.S. Airline SST Committee and Specialist Teams and the corresponding statements of Boeing action were compiled in document D6A10261-1 and distributed to all airline evaluation team members.

Airport Operator's Council Coordination

Engineering assisted in the Boeing SST presentation to the Airport Operator's Council International Conference in Seattle and Renton on September 26, 1966. The primary Engineering assignments were tours of the Mockup and the Technical Briefing Area and briefings on Airport Compatability and Airplane Servicing Features and Locations.

Subcontractors' Visit

Customer Engineering presented briefings, tours, and mockup demonstrations for the subcontractor representatives during their September visit.

Press Visit

Customer Engineering presented briefings, tours, and mockup demonstrations for representatives of the press during their September 29 visit.

Model Specifications

The Model Specification, D6-17850, was completely revised for submittal with the Phase III proposal documentation on September 6, 1966. This revision also incorporated material requested by the FAA during a meeting in August and revisions requested by U.S. domestic and international airlines.

Full-Size Class I Mockup

Construction of the Class I Mockup was completed. See photographs (Figs. 63 through 69) of the completed mockup area. The principal scheduled tours of the mockup are noted elsewhere in this coordination sheet.

Technical Briefing Area

Preparation of the Technical Briefing Area was completed. See photographs (Figs. 70 through 73) of the completed area. The principal scheduled tours of the mockup are noted elsewhere in this coordination sheet.

Fig. 63 Class I Vehicle Mockup

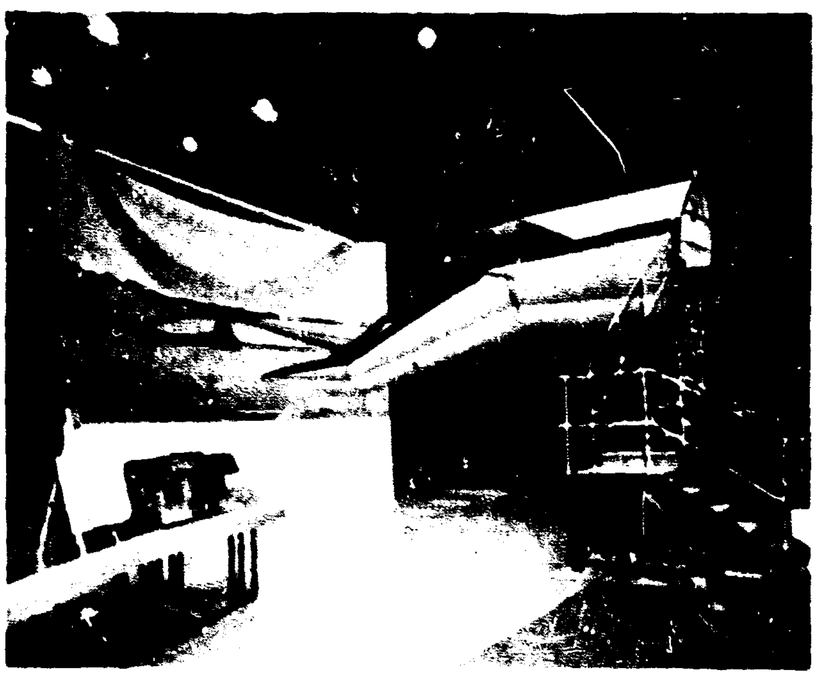


Fig. 64 Airplane Forebody and Flight Deck Mockup

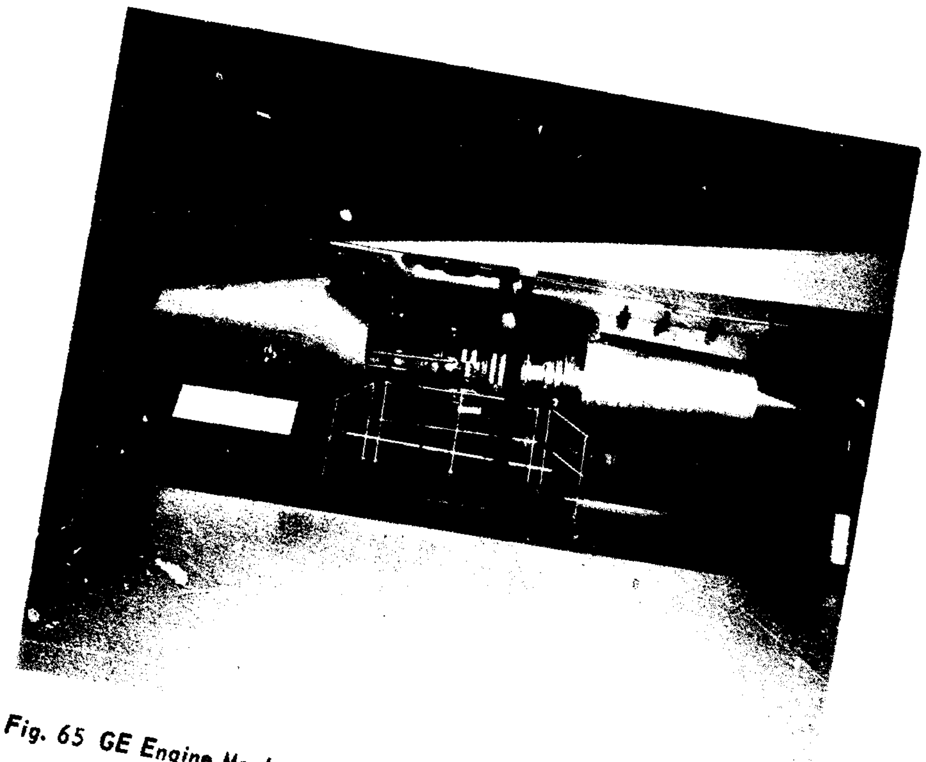


Fig. 65 GE Engine Mockup

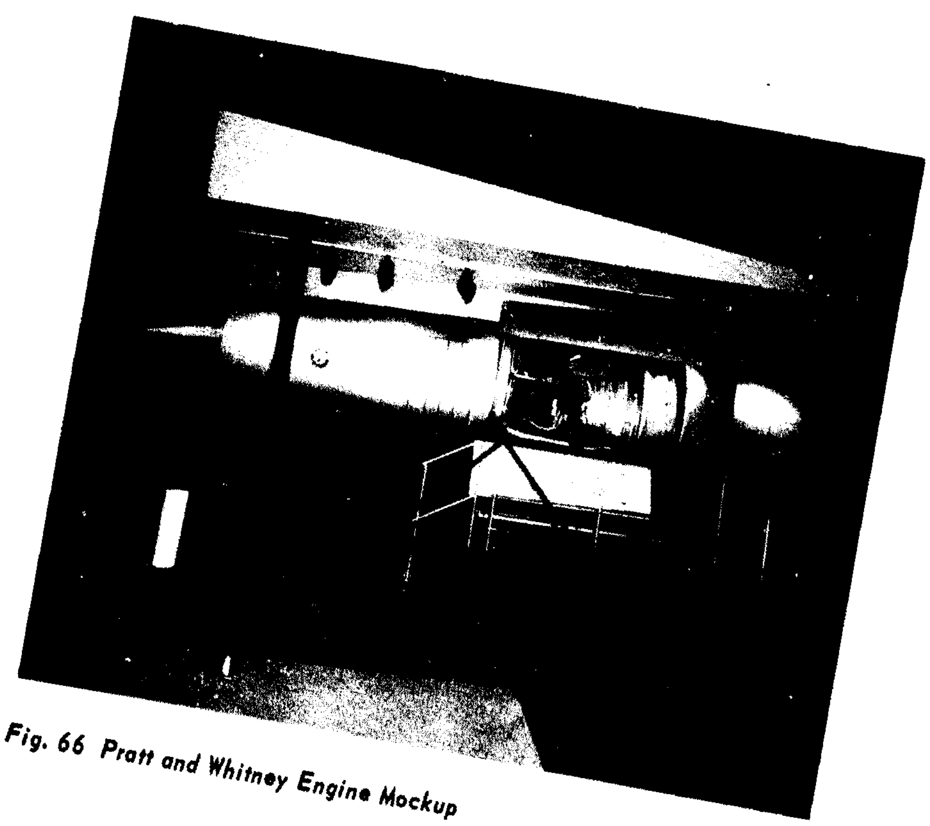


Fig. 66 Pratt and Whitney Engine Mockup

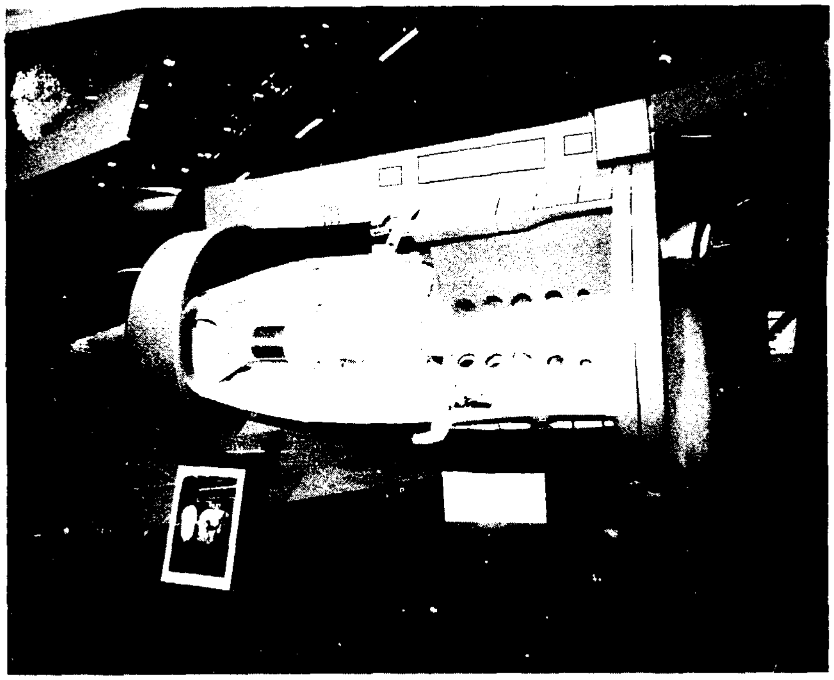


Fig. 67 Full-Scale Engine Inlet Mockup

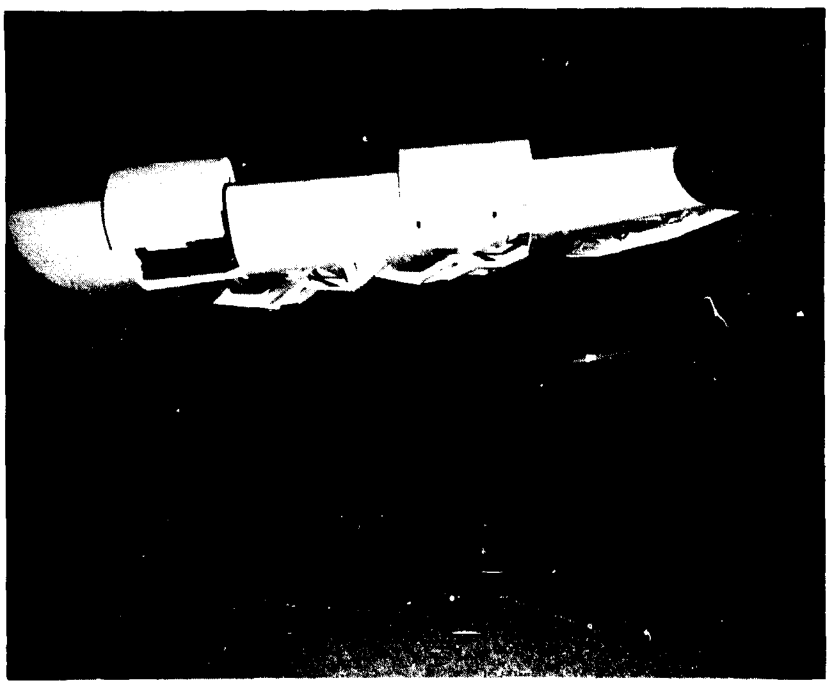


Fig. 68 Accessory Drive System Installation Mockup

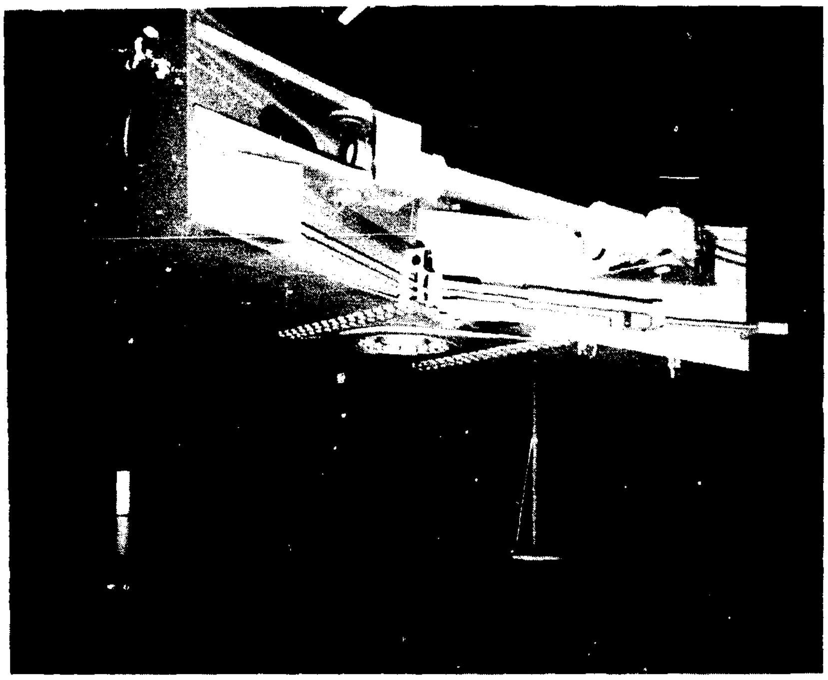


Fig. 69 Full-Scale Wing Pivot Mockup

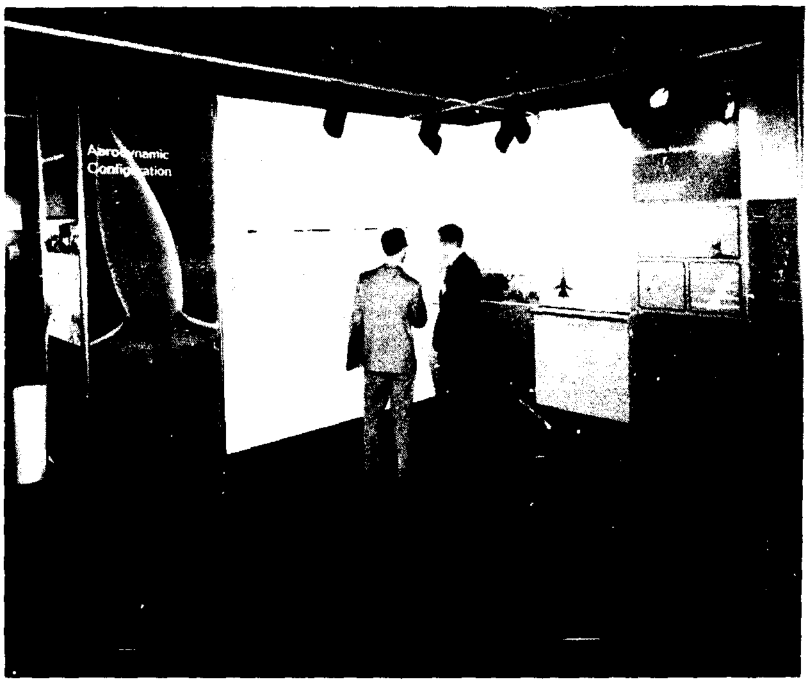


Fig. 70 Aerodynamic Development Section

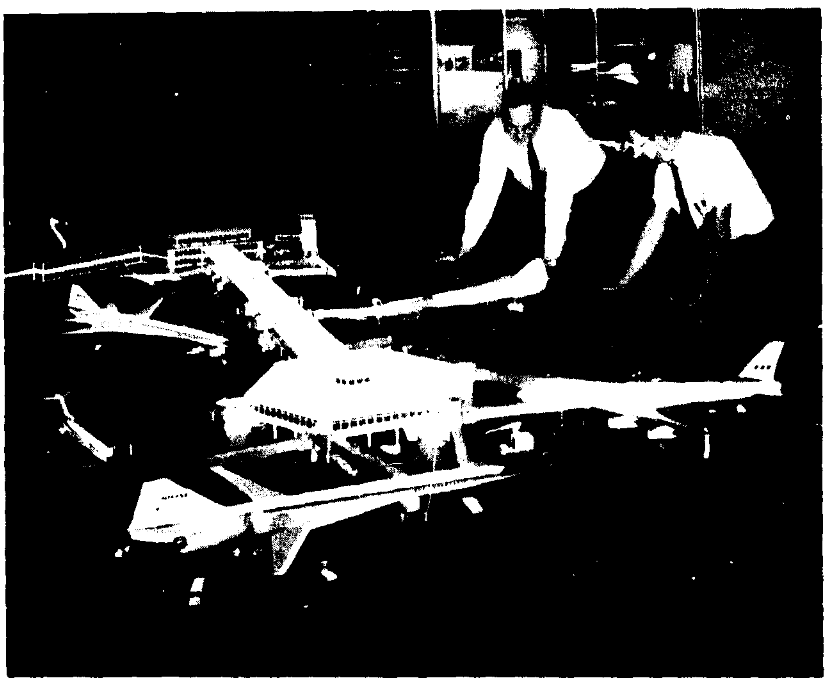


Fig. 71 Airport Compatibility Table

Fig. 72 Engine Inlet Development

Fig. 73 Flight Deck and Passenger Accommodations Area

IV. Airline Coordination (continued)

FAA Coordination

On August 2-3, Engineering personnel traveled to Washington, D.C., for a Model and Subsystem Specification Review with the FAA/SST office.

Customer Engineering assisted in the interdepartmental coordination of the FAA on-site evaluation during the week of September 19-23. Customer Engineering support continued during the Boeing followup on the on-site evaluation.

Approximately 15 transmittals of subsystem reliability analyses, vendor progress reports and other engineering data were forwarded to the FAA/SST office during August and September in response to Phase II-C work plan, personal requests and other requirements.

V RELATED BOEING RESEARCH AND DEVELOPMENT

A. AERODYNAMICS

Studies have been made to determine optimal airfoil shapes for wings having specified depth constraints. The calculations were made with a computer program which combines optimal seeking techniques as described in Wilde.[1]

Example results for a symmetrical airfoil, untwisted wing are shown in Fig. 74. The investigations indicate that wings with contours developed by this procedure may have up to 15 percent less wave drag than wings with more conventional airfoil shape.

B. MATERIALS AND PROCESSES

(1) Low Pressure Diffusion Welding and Brazing

Ti 6Al-4V copper diffusion brazed specimens were tested in air and aqueous salt environments. The base line results for tests in air indicated a satisfactory K_Ic value of 92 ksi $\sqrt{in}$. Tests in salt environments are not completed.

(2) Hydrostatic Metalworking

A visit to several research facilities studying hydrostatic metalworking was made to discuss the process and witness tests on Ti 6Al-4V being conducted for Boeing. The results of tensile tests using a hydrostatic pressure environment are given in Table G. Tests at atmospheric pressure are also shown. The data show a considerable improvement in ductility with increase in hydrostatic pressure.

Table G Effect of Hydrostatic Pressure on the Ductility of Ti 6Al-4V

Heat Treatment	Hydrostatic Pressure psi	Ultimate Strength ksi	0.2% Yield Strength ksi	Elongation % 3D	Reduction in Area %
Mill Annealed (1)	169,000	150	135	16.8	59.3
	397,000	170 (2)	140	27.0	70.4
	506,000	143 (2)	140	32.0	78.0
	Atmospheric	144 (2)	137.5	13.0	38.5
STA (1250) (3)	168,000	130	130	18.0	62.5
	380,000	145	123	29.0	91.6
	463,000	170	150	27.8	88.6
	Atmospheric	154.5	150	7.0	16.0

(1) Considerable anisotropy demonstrated. Initial round cross section became elliptical.

(2) Test not run to failure.

(3) 1900°F 30 minutes Furnace Cool
1725°F 30 minutes Water Quench
1250°F 4 hours Air Cool

[1]Wilde, Douglas J., Optimal Seeking Methods, Prentice-Hall, Inc., 1964.

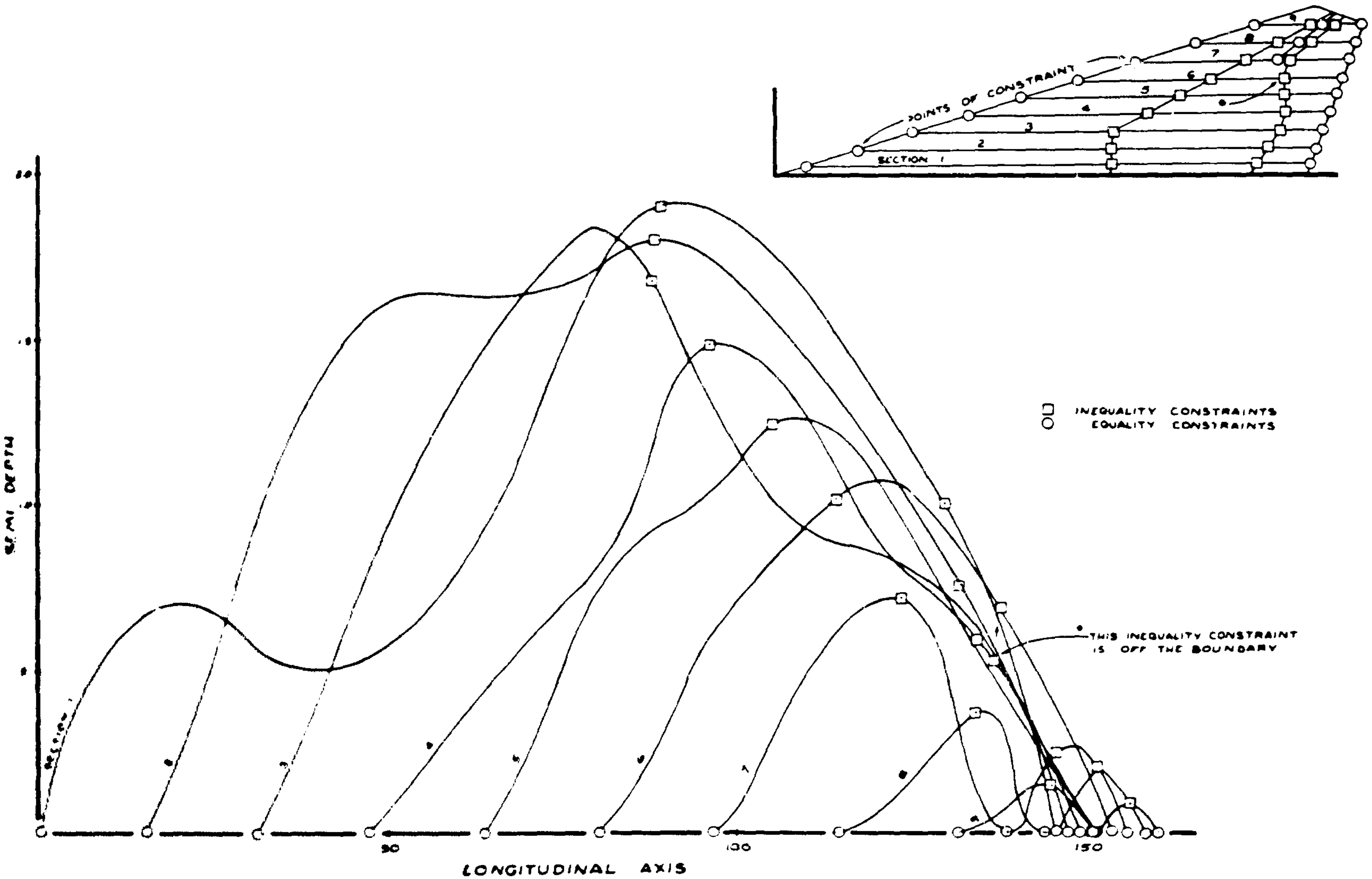


Fig. 74 Optimal Airfoil Shape Study Results

V. Related Boeing Research and Development (continued)

B. Materials and Processes (continued)

Variable Speed Constant Frequency Electrical System

The breadboarded VSCF converters utilizing the new interphase converter arrangement, have been operated in parallel. The match between converter and generator characteristics is now being changed to improve the harmonic content at light load. Additional testing will follow. A generator, converter and filter, utilizing aircraft type packaging, are now in assembly at the General Electric plant.

Microintegrated Circuit Development

A master integrated circuit chip has been designed specifically for use in a family of standard modules for use in airplane 28 volt electrical systems. Breadboard models have been tested. Ten first-class modules have been fabricated using molecular processes. Refining tests are in progress.

(4) Passenger Accommodations - Water and Waste System

D6A10404-1, SST Waste Management Systems Engineering Report was released. The completion of this Phase A Study illustrates the various functional combinations that can be utilized when considering the specific waste management methods. Techniques identified were:

1. Collect, transfer and store
2. Collect, transfer, process and store
3. Collect, transfer, process and dispose
4. Collect, transfer, store and dispose
5. Collect, transfer, process, store and dispose
6. Collect, transfer and dispose

Technique number 2 was disregarded because no operational advantage is gained when the materials are processed, then stored on board for later removal by ground service personnel.

Technique number 3 was eliminated because, after an extensive evaluation, no efficient or satisfactory continuous method not requiring accumulation was found.

The remaining two techniques recommended for extensive research, development and test were 1 and 5.

Technique number 1 is the simplest and its state-of-the-art is the most advanced. This technique utilizes the same functions used in present subsonic aircraft.

Technique number 5 includes the system where the wastes are slurried, incinerated and then exhausted overboard. The existing engine ejector in the tail cone is used for the incineration and exhaust portion of the process.

B. Materials and Processes (continued)

This technique was selected for further study because it could significantly reduce ground servicing and maintenance, and permit shorter turn-around time in the aircraft. The development of an acceptable, reliable waste management system that processes waste materials via incineration, or chemical or physical sterilization, prior to inflight discharge could be most effective costwise.

Techniques numbers 4 and 6 were immediately eliminated, since they both violate quarantine regulations which prohibit inflight discharge of waste materials containing microorganisms capable of causing disease.

Passenger Furnishings and Equipment

Seats

A mockup of the structural portion of a seat design consisting of a filled sandwich type construction has been completed. The purpose of the study was to obtain a lighter seat with improved crash worthiness characteristics. Essentially the principle followed was to distribute the seat loading more uniformly over the seat structure. The study indicates a weight saving of approximately 30 percent as compared to the weight of the structural portion of a conventional seat.

VI STATE-OF-THE-ART RESEARCH

Electrical Systems

A comprehensive trade study and hardware development program has been initiated to establish the most satisfactory means of implementing the landing gear, flap and throttle logic. While this effort is primarily related to the 747 airplane, it is applicable to the B-2707 program. Three basic approaches are being studied and evaluated, namely:

(1) 1/2 size crystal can relays, mounted on printed circuit cards.

(2) Discrete components mounted on printed circuit cards.

(3) Standardized monolithic integrated circuits (NAND LOGIC) and "master chips" mounted on printed circuit cards.

One of the three methods of implementation or a combination of approaches will be selected for the 747 program. It is anticipated that program schedules will allow a further review of the above approaches for selection of the best design on the B-2707.